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ABSTRACT

This document provides abstracts of 116 laboratory experiments/demonstrations currently being utilized in all areas of engineering education at 52 universities across the United States. (SL)

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COMPENDIUM OF CONTRIBUTIONS CLOSE WORKSHOP

ASEE ANNUAL MEETING
UNIVERSITY OF NORTH DAKOTA
JUNE 28, 1977

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C L O S E

Committee for Laboratory Oriented Studies and Experimentation

Historically, CLOSE is the outgrowth of concepts developed in the mid 1960's. Advanced by leading engineering educators throughout the country, these concepts embodied strategies for revitalizing and modernizing laboratory instruction. For several years, CLOSE existed as an ad hoc consortium of engineering educators. Through the efforts of this broadly based group, CLOSE achieved Constituent Committee status within ASEE in 1974.

Today, CLOSE is a viable and expanding group that works toward fulfilling the goals established some ten years ago. Much of the effort is devoted to communication, as it is recognized that no one engineering school possesses the resources to develop and maintain current and vital laboratory programs in several disciplinary areas. Within CLOSE, a broad cooperative effort fosters the development of new software, hardward and instructional strategies for engineering laboratory programs. By providing avenues of communication between faculty, CLOSE enables cooperative development at reasonable expenditure levels. Further, CLOSE works toward providing recognition to faculty engaged in laboratory development.

As CLOSE moves toward divisional status within ASEE, it is providing a forum for communication and presentation of material that impacts upon the improvement of undergraduate laboratory instruction. This forum is multifaceted, and consists of three to four newsletters published each year, involvement with regional ASEE meetings, the program presented at the Annual ASEE Meeting, and the soon to be published Journal for Laboratory Oriented Studies in Engineering. In addition, CLOSE has identified key laboratory faculty at most leading engineering schools, and is developing disciplinary working groups. With this emerging structure, CLOSE can move forward in fostering laboratory programs which are current, cost-effective and vital.

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FOREWORD

The information in this Compendium is directed toward improving communication between engineering educators concerned with the continuing development of pedagogically sound, modern, cost-effective laboratory instruction. This information derives from activities of ASEE's Committee for Laboratory Oriented Studies and Experimentation (CLOSE).

The first solicitation of material for the Compendium was by means of a letter directed to engineering deans, in September, 1976. In this letter, the purposes and historical origins of CLOSE were outlined, and three requests were made: (1) that the letter itself be circulated to faculty actively engaged in laboratory instruction; (2) that a list of such faculty be compiled, by discipline; and (3) that a "laboratory contact person" be identified to represent the addressed engineering school.

Second, in January, 1977, a follow-up letter was directed to engineering deans. This correspondence outlined developments through that date, and provided detailed information concerning the format and procedures for submission of Contributions for this volume. Third, in March 1977, similar information was directed to all persons who had been identified as "laboratory contacts" as of that date.

One of the sections of this Compendium contains a list of all laboratory "areas" which respondents identified as being ones in which they were actively engaged. This list has been reproduced herein in raw form, with no prior attempt at ordering or consolidating laboratory areas. One of the remaining tasks for disciplinary oriented working groups, within CLOSE, is the winnowing of this list into a form which will encompass all essential areas, yet which will be presentable concisely in a format which will foster communication.

Another section of the Compendium consists of a listing of those individuals identified as "laboratory contact persons" for given engineering schools. These individuals are listed by discipline in cases where information was supplied in that format. In other cases, there is a single individual who serves as the point of contact for entire schools or colleges of engineering. Hopefully, this listing will facilitate contact between laboratory instructors, particularly at the regional level.

Further, the Compendium contains a list of the CLOSE membership, as of April 1977. This list should serve a complimentary purpose to that noted above. In addition, there is an index of the contributions contained in this volume, and --the heart of the Compendium-- the contributions themselves.

There are several acknowledgements which should be noted. ASEE Headquarters staff were most helpful in mailings to engineering deans. Joe Biedenbach, Chairman of ASEE's Publications Committee, was

instrumental in encouraging and producing this Compendium. Wayne Bennett of VPI & SU and Rolly Kinney of Oregon State contributed advice, encouragement and support. Angie Perna of New Jersey Institute of Technology contributed historical background on CLOSE. Don Mathsen, of the University of North Dakota, provided liaison and interfacing in several key areas. Finally, special thanks to Susan Andrus, Susan Burns, Rosemary Gebhardt and Chris Paine of the Mechanical Engineering Department of The University of Connecticut for their extra and extraordinary efforts in support of this project.

Stephen L. Rice
Program Chairman
Chairman-Elect
CLOSE

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TITLE OF CONTRIBUTION: Agitation Power Requirements

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The objectives of this experiment are to measure the power requirements of an experimental agitation system, and to correlate the results in a manner which would be useful in scaling-up geometrically similar systems.

Dimensional analysis can be used to determine the variables to be considered for the correlation. For a particular choice of variables, dimensional analysis shows that the Power Number should be a function of the impeller Reynolds Number, Froude Number, and Weber Number for geometrically similar systems. If the system is operated to prevent vortex formation, dependence on the Froude Number is eliminated. If a single fluid is used and no new surface is created, dependence on the Weber Number is eliminated. Therefore, for geometrically similar systems, the correlation anticipated is between the Power and Reynolds Numbers. This correlation is well illustrated by the experiment described here and closely follows the literature. (1)

In our laboratory the Experimental Agitator Kit, Model ELB, manufactured by Bench Scale Equipment Co., Dayton, Ohio is used. Fluids suitable for covering a wide range of Reynolds Numbers are confectioner's glucose (43° corn syrup) with a viscosity on the order of 100,000 centipoises, Blue Label Karo Syrup with a viscosity of about 2000 cp., and water. With these fluids and a 4-inch impeller, Reynolds Numbers ranging from 0.1 to 100,000 are obtained spanning the laminar, transition and turbulent regimes. There are, however, gaps between these fluids. Additional equipment used includes a stroboscope for measuring speed of rotation, a Brookfield viscometer and a Westphal balance.

Data taken include fluid temperatures, rotation speed, torque, and observations concerning presence or lack of baffles and vortexing.

This experiment provides good practice in the uses and limitations of dimensional analysis, opportunities for consideration of problems involved in scaling-up from laboratory experiments, and practice in simple viscosity measurement on Newtonian fluids.

1. Rushton, J. H., E. W. Costich, and H. J. Everett, Chem. Eng. Prog., 49 (4), 165 (1953).

TITLE OF CONTRIBUTION: Centrifugal Pump Curves

AUTHOR NAME: Lawrence G. Focht

AUTHOR AFFILIATION: The University of Akron

AUTHOR ADDRESS: Department of Chemical Engineering
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The objectives of this experiment are to measure and display in the form of typical pump curves the head, efficiency, and brake-horsepower of a centrifugal pump as a function of the flow rate.

In our undergraduate laboratory we do not have a pump test stand. Therefore, the ELD Fluid System apparatus manufactured by Engineering Laboratory Design, Inc., Minnetonka, Minnesota, is used. This equipment is normally used for friction factor measurement, measurement of velocity profiles, and flow visualization experiments.

The additional items of equipment required are a wattmeter and a pressure gauge on the pump discharge. It is assumed that the orifices or other flow meters on the experiment have been calibrated. The wattmeter is connected in the power line to the pump. At various flow rates ranging from shutoff to the maximum flow that can be obtained the motor power input, discharge pressure, and flow rate are recorded.

By applying typical motor efficiencies to the motor power input, the brake horsepower of the pump can be estimated. From this the efficiency at each point can be calculated. These data, and the pump head obtained from the discharge pressure can be graphed versus the flow rate.

Typically the falling head curve, linear brake horsepower relationship, and an efficiency curve which exhibits a maximum value and then falls off, can be demonstrated in this way.

Title: Mechanics of Materials II Laboratory
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The laboratory is an integrated part of a three-semester hour second level course in Mechanics of Materials. The course was designed for Civil Engineering and is required in the CE program. ME students often take the course as an elective. The laboratory consists of a sequence of eight to eleven experiments designed for training the student in all aspects of strain gage technology and a special project on strain gage application and instrumentation. The course is offered each semester to a maximum of sixteen students (because of equipment and space limitations) and has been well received. Students especially enjoy the "hands on" emphasis given to the laboratory sequence. Use of a wide variety of instrumentation for static and dynamic measurements is stressed. The cost for materials is approximately fifteen dollars per student per semester. The laboratory sequence includes surface preparation and gage application, Wheatstone bridge theory, potentiometer circuit theory, bridge balancing, gage factor determination, measurement of static and dynamic strains, use of generalized Hooke's law and use of oscilloscopes, AC-DC amplifiers, pen and chart recorders, power supplies, strain indicators, switching and balancing units, carrier amplifiers, and other electrical components necessary to construct measuring circuits. For detailed information on the course, please contact the author.

Title: Special Problems, Experimental Stress Analysis
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This three-semester hour laboratory course was designed as a senior elective for engineering students to acquaint them with fundamentals of three techniques of experimental stress analysis. Included in the course on a 1/3-1/3-1/3 time allocation are strain gage technology, photoelasticity theory, and use of photoelastic coatings. Basic fundamentals of all three techniques are stressed in a "hands on" practical manner using an introduction to each theory as a base. Being an elective, classes of six to eight are normal for a course of this type, and student response to the course has been quite good. Cost for the course is approximately thirty dollars per student to pay for gages, accessory materials, and plastic. Basic equipment for all three techniques is required, and use of polariscopes (transmission and reflective) limits the enrollment unless staggered sections are scheduled. For detailed information on the course, please contact the author.

Title: Multiplexor Box for Communications Experiments

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Many forms of modulation and multiplexing can be effectively demonstrated in the time-domain by an analog multiplier, two signal generators and an oscilloscope. Double sideband modulation (DSB) can be generated by inserting the modulation signal and carrier into the two inputs of the multiplier. Conventional amplitude modulation (AM) can be displayed by adding an appropriate offset to the modulating signal. Either waveform can be demodulated coherently using a second multiplier and lowpass filter. Time domain results are displayed on an oscilloscope while frequency domain results can be achieved with a spectrum analyzer plug-in. Pulse amplitude modulation (PAM) can be demonstrated by replacing the sinusoidal carrier with a pulse generator. Burr-Brown manufactures a 4203J multiplier which sells for $26. Input loading and distortion are negligible and external offset adjustments are not required. The multipliers require ±15 V power supply and are rated for less than 1% amplitude error to 40 kHz. Carrier frequencies of 1 MHz have been used without undue distortion of the output.

More sophisticated techniques such as multiplexing (FDM, QM or TDM) and single sideband modulation (SSB) require two multipliers for modulation and two for demodulation plus a summing amplifier. Noise can also be introduced by a second summing amplifier. Using a separate box for each component requires extensive wiring just for power and generally leads to student confusion and errors. Consequently, we have constructed a multiplexor (MUX) box which contains four BB4203J multipliers plus two 741 operational amplifiers wired for X1 and X10 gain. The six I.C.'s are wired on a P.C. board and enclosed in a chassis box measuring 9 x 7 x 2". External inputs to the box include ±15 V and ground from the power supply plus two inputs and one output for each element. The MUX box is much appreciated by students and instructor alike since wiring errors are less likely and easier to spot. The MUX box is used in five different experiments in the communication laboratory. Copies of the P.C. board and box layouts are available upon request.

Title of Contribution: THE FIRST ELECTRICAL LABORATORY

Author Name: Russell E. Lueg
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Almost all students in the College of Engineering take a lecture-laboratory course entitled Electronic Instrumentation, which emphasizes dc circuits, solid state devices and the practical application of electronics. The laboratory portion consists of:

1. The Oscilloscope. A three week introduction to the oscilloscope using self-paced instruction, with a laboratory manual written by C. H. Roth, as well as traditional assistance by professors are utilized. A practical and written test on the oscilloscope are given at the beginning of the fourth week.

2. DC Ammeters and Voltmeters. Voltmeters and ammeters are constructed from a basic 15 mA d'Arsonval meter movement and associated resistors.

3. Digital Multimeters. Proper use of the three functions of a DMM are practiced.

4. Measurement Techniques. Loading and frequency response limitation of the oscilloscope and DMM are observed.

5. Nonlinear Graphical Analysis. Light bulb v-i characteristics are plotted. Circuits, in which the bulb is used, are analyzed theoretically and experimentally.

6. Diodes and Applications. An introduction to characteristics, the use of diodes in circuits, and the use of a curve tracer are a part of this lab.

7. Transistor Amplifier Design. Graphical analysis and measurement of gains are emphasized.

8. Temperature Regulator. Thermistor, transistor and relay characteristics are measured and then assembled to build a temperature regulator. An op amp is used in the second part of this lab.

9. Strain Gauge Indicator. A strain gauge used in a Wheatstone bridge, a transistor, a diode bridge, and a microammeter are used to measure and indicate strain in an aluminum bar.

10. SCR Power Control. R-C networks, SCRs, Triacs, Diacs, and magnetic switches are used. Some instructor demonstration.

11. A practical lab final is given.

Title of Contribution: FRESHMAN LABORATORY PROJECTS

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A course designed to motivate and encourage freshmen students to remain in engineering has proven to be quite successful. The highlight of the course is a series of projects that require interaction between the students and representative faculty of all departments. A list of some of the projects follows:

1. Dirigible Design. A helium filled balloon with appropriate fins and weighting must fly straight and level (Aerospace Engineering)

2. Fluid Flow in Pipes. The self mixing of fluids in pipes are observed and measured (Chemical Engineering)

3. Model Span Project. The students build balsa bridges and load them to structural failure (Civil Engineering)

4. Radio Project. A simple crystal radio is coupled to an operational amplifier to boost output (Electrical Engineering)

5. Parcel Design. A small, lightweight parcel must protect a hen egg inside when dropped from a height of 40 feet (Industrial Engineering)

6. Auto Design--By Computer. Fuel economy is the goal for this project. Some excellent sketches of cars are obtained. The students use the University's digital computer for the first time (Mechanical Engineering)

7. Foundry Project. Students make molds, see the metal poured and take home a souvenir aluminum elephant or ash tray (Metallurgical Engineering)

8. Mine Development. Slides of mines and mining equipment are shown. Characteristics of the various mineral samples are discussed (Mineral or Mining Engineering)

9. Other Activities include a project in the Engineering Library, a discussion of Careers in Engineering, and an optional array of projects involving solar cookers, industrial scheduling, auto pollution, paper airplanes, industrial pollution and field trips.

Title: NONENGINEERING STUDENTS IN A LOGIC DESIGN LABORATORY

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A twenty unit self-paced course in logic design with no EE prerequisites includes four laboratory exercise units. Initially, there was concern about the ability of nonengineering students (Computer Science, Mathematics, Computer Based Honors Program, etc.) to operate effectively in an unstructured laboratory environment. To overcome this lack of technical expertise, logic trainers are utilized at the functional level. Not only do the nonengineering students perform well in the laboratory tasks but most of them approach the laboratory design exercises with an eagerness equal to that of their engineering cohorts. Each individual designs (say a binary counter of some specified sequence) implements, tests, troublesnoots his/her prototype to successful completion giving them a sense of accomplishment and pride frequently missing in the more structured laboratory.

Two levels of logic trainers are used. The first laboratory exercise is performed with trainers having AND, OR/NOR logic gates. A logic problem is assigned to each student and through the use of truth tables and Boolean algebraic manipulations (simpler techniques such as Karnaugh mapping have not been introduced as yet) the student obtains a Boolean function of four variables which he/she then implements.

The second level of logic trainers is composed of NAND gates of various numbers of inputs and J-K flip-flops and is used for three laboratory exercises. One exercise requires implementation of several functions of four variables. Commonality between the functions offering efficiency of gates through shared terms is one of the design objectives. Two exercises deal with sequential networks. Typically, one exercise requires the design and implementation of a counter of some specified count sequence and the other requires a system to detect certain binary sequences occurring in a serial binary stream.

The role of the instructor usually is to lead the student to an understanding of a logical rationale for troubleshooting when an implementation fails to meet the design specifications. As long as the student is making progress, no attempt is made to intervene or force time constraints.

In summation, with careful planning, laboratory environments were created in which the nonengineering student competes successfully with his/her engineering colleague and shares the same satisfaction that emanates from participating in the practical application of the theory learned in the classroom or from the textbook.

HEAT POWER LABORATORY

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The heat power laboratory in Mechanical Engineering at BYU is the transition laboratory used to not only imbed the thermodynamic principles involved firmly in mind, but to begin the process of introducing the students to the graduate engineers world of producing his own test programs and procedures. The laboratory is included within the second course in thermodynamics for 4 semester hours credit.

Laboratory groups of 3-6 team members are permanently assigned for the course. Each lab group must produce 7 reports on 7 experiments in which only general objectives are given. The students are expected to design the test procedure and select instrumentation based on previous knowledge of single sample statistical error analysis. They must accomplish the test objectives, write a brief report based on a simplified format that is ready for a secretary to type in final form. They are allowed two, three-hour lab periods in a two week sequence to accomplish the task, and they must meet a deadline on time.

Their test proposal is approved by a teaching assistant who pre-tests the group on each experiment to assure they have properly thought through their program before testing begins. One report per group is submitted, read by the T/A and graded by the faculty.

The range of experiments cover complex interacting systems like a rankine cycle steam turbine with superheat where many readings and operations must be coordinated, to standard high precision experiments like a Parr Bomb heating valve of a fuel. The students have previously had the usual physics lab and a 2-hour instrumentation lab class plus a statistics class and a first course in thermodynamics.

The report produced and the testing done must be a group effort that meets a time schedule with little slippage. Thus the student begins the process of (a) meeting time schedules, (b) designing his own procedure based on objectives and error analysis, and (c) must produce a group effort. The work to be accomplished in the time period exceeds what one individual can do alone.

Experience indicates that while reports are often ragged and meeting deadlines hectic, the students have almost universal compliments on the laboratory.

Electric Machinery Laboratory Equipment. A. N. Chaston, Electrical Engineering Department, Brigham Young University, Provo, Utah 84602.

There are four types of Electrical laboratory machinery equipment in use. These include, 1) 2-5 hp machines, 2) 1/20 hp machines developed by Michigan State University for control type work. These are available from Scott Engineering Sciences, Pompano Beech, Florida, 3) 1/10 hp machines developed by Rensselaer Polytechnic Institute of Troy, New York for use in explaining utility and power oriented equipment and, 4) 1/3 hp size machines from Hampden Engineering Corporation, East Longmeadow, Massachusetts.

We have used three of the four types of equipment at BYU. The larger types of machine were abandoned because of the huge space requirement, maintenance, and unavailibility of additional synchronous machines. However, the large equipment did provide the student with a greater respect for electric machines.

The second group of machines are excellent for explaining control and feedback concepts but are limited in showing and explaining the behavior of larger types of equipment. For example the dc machines must be armature controlled rather than field controlled. Also, some of the machines must be specailly machined and are therefore unnecessarily expensive. We do continue to use this equipment in our control laboratory on a somewhat limited basis.

The third group of equipment was developed at Rensselaer Polytechnic Institute. These equipments are G.E. stock items with a special coils added so as to measure magnetic flux. Because of marketing policies, they are available only in complete sets of 2, with replacement items unavailable. This equipment was developed for use by students in senior or graduate programs. They permit many innovative experiments in the electric power field.

The fourth type of equipment available for purchase from Hampden Engineering, offers excellent characteristics at a relatively inexpensive price. The equipment is large enough to provide an excellent model of larger type equipment and yet small enough to fit on a small work bench and to be stored compactly. They were originally designed for trade and high schools. With some innovations they are also appropriate for university work. We have added a torque sensor available from LeBow Associates, Inc., of Oak Park, Michigan. This permits the use of X-Y plotters to obtain torque-speed curves, etc. One advantage of the Hampdem equipment is that only two machines are required for most all machine experiments. One is a DC machine which operates either as a motor or generator and incorporates appropriate coils for use as either a series, a shunt, or a compound machine. The second machine is a wound-rotor induction motor which can be used for all types of wound-rotor experiments. A squirrel-cage machine is simulated by shorting the rotor windings and an excellent synchronous machine is obtained by applying a dc voltage to the rotor assembly. We use a third machine, called a multi-purpose machine, which is a single-phase capacitor-start motor to which appropriate components have been added so as to serve as a split-phase, capacitor start, fixed capacitor, and two capacitor single-phase motor.

To be noted is that much of this equipment can be obtained as off the shelf items when purchased from the original vendors. This avoids middleman markup and effects considerable savings.

Description of a Workable Chemical Engineering Laboratory

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For several years the chemical engineering laboratory course covering experiments in heat transfer, fluid flow, thermodynamics, mass transfer, kinetics and process dynamics has suffered the problems of low student moral, of late reports and of generally poor response by students to the learning experience. By changing the format of the course and by upgrading the experiments, a course without the above listed student problems has been obtained. The new format has met with both student and faculty approval and has resulted in many of the faculty's becoming involved in suggesting new experiments and scheduling time in lecture class for mini-experiments to be carried out in the laboratory. Because of space restrictions only an outline of the new format for the course will be given below. It is believed that this outline is applicable to a wide variety of laboratory courses.

Course - Two semester, 2 hr/semester, 6 contact hrs/week senior chemical engineering laboratory course.

Attendance - Attendance is required each period for the entire period. Permission to leave laboratory is required. Laboratory is likened to position in industry with respect to an individuals responsibility to be to work on time and to put in required time.

Personnel - Available and in attendance during the complete laboratory period is a faculty member, a full-time laboratory technician and a graduate student teaching assistant. Having these people available and expressing an interest in the students has been the one largest factor in improving student moral.

Assignments - Five experiments are required each semester. Students work in groups of two, change partners every experiment, and never have the same partner twice in a semester. Students find they can put up with differences in academic ability, personalities, etc. between partners for one experiment, whereas its much more difficult for an entire semester. A laboratory notebook is required of each student and is periodically reviewed with the student.

Reports - Five reports each of a different format are required. By having different formats, student interest in writing is kept high throughout the semester. The formats are:

1st report	Oral (given before entire class)
2nd report	Informal or short (6-14 pages)
3rd report	Formal (10-20 pages)
4th report	Journal (uses a scientific journal formal, 6-12 pages)
5th report	Letter (one page with extensive appendices)

Aids - Several learning aids are made available. These include most of the standard reference books and course books used in chemical engineering and related fields, drawing instruments and light tables for use in preparing reports, and individual computer funds of approximately $10/student.

Based on the above format, our laboratory course has been revitalized and has become a stimulating experience for all involved.

DIGITAL LOGIC LABORATORY--RICHARD OHRAN, ELECTRICAL ENGINEERING DEPARTMENT, B.Y.U.
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The Digital Logic Lab at Brigham Young University is the result of a joint effort by the Departments of Computer Science, Electrical Engineering and Technology, and greatly enhances the teaching of digital logic.

The lab was needed to satisfy instructional goals for all three departments involved. Computer Science students needed a better basic understanding of digital logic, without requiring a specialized knowledge of electronics.

The increasing prominence of digital techniques in electronics dictated a need for all electrical engineering students to have an exposure in digital logic, and those students specializing in digital logic needed an in-depth laboratory experience.

Using ideas from Chuck Seitz of the University of Utah and $10,000 diverted from departmental operating budgets, work on the lab was started in the fall of 1971.

Much of the work we did ourselves, including the overall design and construction, fabrication of printed circuit boards, tools and connectors. With such a small budget, we relied heavily upon volunteer student labor to complete the work.

By the fall of 1972 the basic lab was completed and now consists of 100 stations, 150 logic panels, 2,000 logic cards, 30 tool sets, 30 power supplies and a variety of test equipment and accessories.

The lab is able to accommodate students from Computer Science, Electrical Engineering and Technology in three levels of labs: Basic and Advanced Switch Circuits, and the Advanced Digital Systems Lab with a total of 255 students enrolled.

There is enough room and equipment to handle 1 to 2 students per station in each lab.

The design facilitates quick assembly and what might otherwise have taken 3-4 weeks can now be accomplished in one lab period.

Debugging time is also greatly reduced, thus allowing a greater penetration into the theory of digital logic by each student.

Each station is built well enough to withstand repeated use. After five years, the equipment is still in good repair.

The modular design minimizes non-digital aspects and encourages interdisciplinary participation.

All of this has enables students to participate in a wide range of simple-to-complex projects.

Now five years old, the lab is becoming an increasingly important part of the curriculum and we are continuing to improve and expand its facilities. We have also developed an Advance Systems Laboratory, incorporating many computers, microprocessors and a variety of peripherals.

One real problem is the lab's increasing popularity among researchers in various departments on campus. It is becoming more and more difficult to restrict the use of the lab to teaching rather than research purposes.

Considering the cost in time and money, and its contribution as a teaching aid, the Digital Logic Lab has been one of the most productive investments we have made, and promises to play an even more vigorous role in the future.

Civil Engineering Department

GEOTECHNICAL LABORATORY INSTRUCTIONS

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The laboratory instructions in the geotechnical laboratory is divided into basic soil properties and the strength and compressibility characteristics of soil. In the instructions of the basic soil properties of soil, considerable emphasis is placed on the physical chemical properties of fine grain soils. Demonstrations are performed using sodium saturated bentonite subjected to different environmental conditions to illustrate the change in properties. Differences in the soil properties are related to the physical chemistry of soil water system.

Basic soil tests performed include partical size distribution analysis, soil moisture density relationships, inplace density tests, laboratory permeability tests, visual identification of soils. In performing the various tests, real soils taken from actual construction projects are used. The significance and meaning of each test as applied to the particular construction project is illustrated and emphasized. For example, in performing atterberg limits on a saturated clay having to do with foundation studies for multi-story buildings the following practical points are made.

1. If the natural moisture content is equal to or greater than the liquid limit the soil is likely to be normally consolidated.
2. If the natural moisture content is equal to or greater than the liquid limit the soil may be sensitive to disturbance.
3. If the natural moisture content is approximately equal to the plastic limit, the surface material is likely to be overconsolidated.

In the above illustration undisturbed samples are provided so that the actual moisture content can be obtained along with the determination of the atterberg limits, permitting an evaluation of the soil characteristics based on the three statements outlined above.

Tests performed to evaluate the strength and compressibility characteristics of soils include one dimensional consolidation test, unconfined compression tests, consolidated undrained traxial shear tests on clay, consolidated drained traxial shear tests on clay, consolidated drained traxial drained tests on sands and direct shear tests.

In performing the above tests the same philosophy outlined above for soil properties is used. Soil form actual projects are used in the above test. Considerable emphasis is placed in relating the tests to field performance. In most cases, the performance characteristics of the soils used in the actual field problem is available and the principles involved in applying the test results to an actual problem is discussed. For example, if the test sample is a highly compressible material, the affect of this characteristic on foundation performance and the type of foundation required is emphasized.

Final Year SYSTEMS LABORATORY in Electrical Engineering

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For some years now we have met the fourth or final year laboratory needs by a reasonably unstructured laboratory which is project oriented and where student initiative is encouraged.

The projects are provided by all the final year instructors supplemented by some student sponsored projects where Faculty agree to supervise. Projects are normally 6 weeks long, with some running a full term (12 weeks).

Students are free to select their projects within equipment limitations. (At times the small computer oriented projects are so popular that the laboratory has been open nearly 24 hours a day.)

Typical of the small computer projects are mini/micro computer construction and programming, microprogramming, colour image display, speech verification and coding, design of electromyographic input channels for MECON* and control telemetry channels for it.

A number of system problems are investigated on the university computer, such as multiloop control system design, power system and machine stability, transients on power lines, and computer-aided design and graphics.

Other projects involve a phase-locked loop servo system, microwave measurements and components, and the making of an integrated circuit.

The major student initiated project this year is an electric car using an induction motor drive.

*Acronym for 'Modular Environmental CONtrol Device' for a highly disabled person.

NOVEL EXPERIMENTS IN UNDERGRADUATE CHEMICAL ENGINEERING

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Undergraduate laboratories in engineering schools are usually vested in fixed apparatus that is expensive to install and time consuming to modify. As a result the "experiments" become rituals which are handed down from year to year and "written up" by a long line of the faithful, who obediently bend their data to fit the venerable equations which represent the established doctrine of the profession. Although these traditional laboratories serve the important function of illustrating the principles of engineering, they certainly do not encourage creativity in our neophyte engineers.

To encourage real experimentation, this department has introduced a series of "novel" experiments into its undergraduate laboratories. Such experiments have been a regular feature of the third and fourth year unit operations laboratory since 1970 and were tried with second year for the first time in 1977. In second and third year each group (2 or 3 students) has a different project, to be completed in one four hour period or in three, three hour periods respectively. In fourth year each group works for three, six hour periods on a single project which evolves throughout the year.

Novel experiments are always one of a kind experiments which have not been previously done in the department and for which there is no established result. Some typical examples are:

Second Year - Devise a method, then carry out the separation and recovery on "beaker" scale, of powdered zinc oxide and cupric carbonate.

Third Year - Examine the feasibility of sugar coating peanuts in a spouted bed.

- Build a continuous coffee machine with a capacity of 3 cups per minute.

- Examine the feasibility of extracting aluminium from sea water by ion flotation.

Fourth Year - Build a 50 watt zinc/air battery using Teflon bonded cathodes.

- Examine the feasibility of producing furfuraldehyde from saw dust.

These novel experiments are generally well received by students, who feel that they are more interesting than the standard experiments. However there are some difficulties. In particular it is hard to conceive of new projects that can be completed within the constraints of the program. It is also difficult to supply equipment and facilities for so many "one of" projects, and in many cases the work required is underestimated so that students spend extra time completing the projects.

Despite these problems we feel that the novel experiments have a useful role. Such projects throw the students on their own initiative, force them to solve unstructured problems and let them do a little experimentation with their own ideas. All of which are desirable features of an engineering program.

FLUID POWER ENGINEERING CIRCUIT BOARD

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'Fluid Power Engineering' can only be cursorily taught at a component description and circuit application level, and to become meaningful needs to extend into full cycle analysis and design of multi-actuator sequencing circuits. However, the design of complex circuits by itself is limited without the opportunity for students to build, test and encounter problems in the circuit logic and in the design techniques. Unfortunately the excessive time required to build even the most modest circuit, together with oil handling and air entrapment problems, normally prohibits it as a practical laboratory exercise. In fact laboratory work tends to be restricted to the determination of power and efficiency characteristics in variable and fixed capacity pump/motor circuits.

A portable laboratory apparatus was developed, and has been successfully used for a number of years with a final year undergraduate 'Fluid Power Engineering' course, to enable the students to simulate the construction and testing of multi-actuator circuits. The apparatus uses air as the circuit fluid but serves to adequately demonstrate the behaviour of oil filled systems as well. It comprises a wide range of components fitted with quick disconnect couplings and mounted on to a 4' x 8' portable black-board. With selected lengths of plastic tubing similarly fitted with mating couplings the circuit elements may be readily combined to form circuits of high complexity. The circuits thus constructed provide an immediate illustration of logic and technique. A standard laboratory air-line or a small portable air compressor give an adequate volume and pressure supply to operate the system (supply pressure between 40 and 80 psig).

The Circuit Board consists of one rotary and three linear actuators, together with 8 flow and pressure controls and 32 directional valves. The directional valves are mainly of a 2 position-5 connection type with a range of combinations of actuating signals such as manual/indent, manual/spring, pilot/spring, solenoid/spring and solenoid/solenoid, etc. A switch panel is used to connect any of the solenoid operated valves to microswitches activated by the three cylinders. Relay circuits built into the switch panel enable the solenoids to be used in a 'continuous' or 'interrupt' model. That is the option exists for the solenoid signal to be retained until cancelled by further activation of the microswitch.

Normally the circuit design requirements are specified for the students and a complete cycle analysis and circuit diagram is prepared before the laboratory period. Thus, the laboratory time is spent in constructing, testing and usually modifying the circuit. An example of the type of project undertaken is the complete design of an 'Automatic Hydraulic Drilling Machine'. The operations include locating and clamping the workpiece on the machine, switching on and off the drill-motor, fast and slow traverse of drill bit and final component release.

Cost of all the circuit components, couplings and other material for the circuit board was approximately $1,500.

LABORATORY CREATIVITY

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According to students presently in the flexible pavement laboratory it is run on a "philosophy of participatory creativity by which the extraction of experience and information is a function of individual desire, encouraged on an informal and non-regimented basis." "In most engineering laboratories you just test the material, in this laboratory you design, mix, and text the samples."

This laboratory which does not have a laboratory manual, definite experiments with a structured form, nor strict time deadlines, appears to create in the student confidence in his ability and a feeling of accomplishment along with other students under the guidance of the professor.

The method of instruction involves a combination of audio-visual and lecture to achieve course objectives leading class participants into a practical overview of the flexible pavement world. In the asphalt laboratory the student population varies from 10 to 16 as it is a senior elective. Each student is assigned one, two, or three pieces of equipment to be his responsibility. He is to find the equipment, read about it in the ASTM, manuals, and textbooks, compile a written report and become familiar enough with it to explain its operation to the rest of the class. According to one student, "By explaining to others how to use the equipment the students really learn how to use the equipment."

The availability of representative asphalt testing apparatus in the laboratory helps the student prepare for actual and professional application of the techniques of design and testing of asphaltic cement pavement. After the class becomes familiar with the pieces of equipment, they work in one or two groups to perform a sieve analysis on six bins of raw aggravate which are brought in from a hot plant each year by the students themselves. Tests performed on the asphalt include: penetration, ductility, and viscosity. Each student then does an individual design and two of these are selected for use in making mix samples in the laboratory. When the techniques have been mastered, the samples are used in Hveem and Marshall tests.

The professor's fifteen years experience in the industry and close contacts makes possible field trips to Douglas Oil Company's asphalt laboratory, an asphalt hot plant, and asphalt paving jobs in the area. The class becomes aware of current trends in the asphalt pavement business first hand.

Due to a lack of space and budgetary constraints we have a concrete mix design laboratory and an asphalt pavement laboratory in the same 30'x30' room. We are fortunate to be able to schedule the concrete laboratory in the fall quarter and the asphalt laboratory in the spring quarter since the materials and equipment in most cases vary considerably. At the end of each quarter the respective equipment is cleaned up and put away to make way for the new quarter with the new laboratory.

Student response has been most encouraging: "I didn't realize that being in the field and seeing things more closely was this interesting." "The asphalt pavement design class is the best laboratory I have had during the past three years at Cal Poly."

5/77

Title: To establish existing and desirable methods, conditions and attitudes towards laboratory oriented courses.
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This is an attempt to quantize the existing and the desired state of affairs as pertaining to Laboratory oriented courses. This data would enable the engineering educators to optimally allocate their resources. Also, this data would establish some norms and standards for the laboratory oriented courses. To this end the following questionnaire is proposed. The questionnaire refers only to Engineering Laboratories and courses.

	That are Existing	You prefer to Exist
1. a) The total number of Laboratory courses in entire Engineering curriculum	____	____
b) Of these how many are in the major Engineering discipline of the student	____	____
2. a) The number of Engineering Laboratory courses mandatory for graduation	____	____
b) Of these how many are in the major Engineering discipline of the student	____	____
3. The number of weekly contact-hours per unit credit of a Laboratory course.	____	____
4. In the past two years how many Laboratory courses were taken by an average graduate	____	____
5. The number of Laboratory courses that are corequisite to a lecture course	____	____
6. The Laboratory courses that are prerequisite to a lecture course	____	____
7. The percentage of the Laboratory equipment that was:		
a) Purchased commercially	____	____
b) Developed in-house	____	____
c) Other (Specify) _____	____	____
8. The percentage of Laboratory equipment that is:		
a) Less than five years old	____	____
b) More than five but less than ten years old	____	____
c) More than ten years old	____	____
9. The percentage of experiments in a Laboratory course that are:		
a) Exercise oriented	____	____
b) Test oriented	____	____
c) Simulation oriented	____	____
d) Design oriented	____	____
e) Other (Specify) _____	____	____
10. The percentage of Laboratory courses that are taught by:		
a) Regular Faculty Members(Asst., Assoc. and Full Professors)	____	____
b) Full time or Adjunct Lectures/Instructors	____	____
c) Graduate Assistants/Research Associates	____	____

THE VALUE OF MUDDLING THROUGH

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After years of muddling through life I've decided this is the only way to go: to learn by trial and error. After all, isn't this the reason we provide for laboratory work in our curricula? Students and instructors alike are provided with sufficient hardware with which to fool around until, having made enough mistakes, some new reality appears evident to them. And I doubt that these new realities can be called knowledge until certain truths are discovered through first-hand experience. It is through our failures that we weave the fabric of success.

Students generally dread laboratory courses, mainly out of resentment at having to invest so much time for such little academic credit. Performing experiments, sorting out data, calculating results, writing it up is tedious and time-consuming at best. When things go badly it's even worse because in spite of time spent there is an absence of success. Result: students often use a hit-or-miss approach in which the idea is get it finished as quickly and painlessly as possible. Naturally such tactics make it even more difficult for them to understand what is the purpose behind any experiment.

Still, nobody can blame them. Under the pressure of demands from concurrent theoretical problem-oriented courses little time is left to allow the student full enough scope to worry his way through to successful results. Not understanding conceptually what is required, the student will blindly read procedures. In his hastily thrown-together report he often misses the whole point of the experiment: results don't make sense and discussions are inconsequential.

One approach lies in convencing the student to stop his busy work long enough to figure out what are his experimental objectives, then to formulate plans to fulfill them. If enough preliminary thought has not been given, trouble generally follows, causing the usual pain and discomfort to student and lab instructor alike. At that point of discomfort, however, the learning process begins: when the student realizes he's screwed things up he usually yells for help. Only at this point will I give it, and then in small hints and dribbles geared for keeping the student pointed in the right direction. He must make his own mistakes and learn from them, or no real knowledge can come from the experience.

The benefits of letting a student muddle through is experiments cannot be overstated. We learn from our own clumsy mistakes providing nature allows us that luxury. What better time than in undergraduate engineering laboratories for goofs to occur? Certainly no wisdom is possible until we grasp the reality of our own ignorance.

THE BERKELEY COMMUNICATION LABORATORY

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The Berkeley Communication Laboratory is used for a fourth-year two-quarter course that complements a parallel lecture course on communication theory and systems. The underlying precept in the design of the Laboratory was to enable the student to do experimental work at the same level of sophistication he encounters in the lecture course, i.e., to establish a parity between the empirical and theoretical insights offered the student. To do this, it was necessary to provide equipment for investigation of such concepts as spectral analysis, bandwidth expansion in modulation systems, sampling, aliasing, quantization, bandwidth/signal-to-noise ratio (SNR) tradeoffs, thresholds, etc.

The vehicle by which such a level of sophistication is achieved is a stand-alone work station containing all necessary experimental equipment for two quarters of experiments. The student spends his entire time during the course at a single station in the Laboratory, successively reconfiguring it by front-panel switching into a variety of AM, FM, and PCM systems, and making measurements of waveforms, spectra, and SNR's at various points in these systems.

All laboratory equipment is replicated in multiple independent work stations, a strategy that has many advantages over the more traditional arrangement of having a separate apparatus for each experimental topic and rotating these apparatuses among students during the term. First, all students can do the required experiments in their natural order, rather than in an order dictated by the combinatorics of exchanges of apparatus. Second, a student can progress at his own speed, and can even backtrack to check suspect results, without conflicting with other students for the use of equipment. Finally, quirks and inaccuracies in the student's work station quickly become well-enough known to him that he can compensate for their effects in evaluating and comparing different experiments. (In the usual laboratory, a student's experience with a given apparatus is often so brief that he has no way of distinguishing true experimental results from those due to the subtleties and vagaries of the apparatus.)

Because of the complexity of the experimental equipment and procedures, and of the underlying theoretical material, a rather elaborate two-volume laboratory manual is used. One volume summarizes, without extensive use of statistical concepts, the necessary theory concerning spectrum analysis and AM, FM, and PCM systems. It serves as a single-source reference volume against which experimental results can be compared. It also permits the motivated student who prefers to gain experimental insight before full exposure to theory to achieve enough understanding of the theory to pursue the experiments prior to taking the lecture course.

The second volume of the manual is concerned with the experiments themselves. It is designed to minimize the time the student spends in learning experimental techniques, and to maximize the time he spends in achieving an understanding of communication systems per se. To attain these objectives, the second volume is in the format of a workbook. Procedures are given in great detail, and blank tables and graphs, properly laid out, are provided at appropriate spots for entry and plotting of data. Questions are interleaved among the experiments, and blank spaces provided for answers, so as to insure that the student has fully considered the implications of the results he has obtained.

A complete description is in the IEEE "Communications Society" magazine, March 1976, pp. 12-21. Reprints are available from the author.

FUNDAMENTALS OF ELECTRICAL ENGINEERING

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"Fundamentals of Electrical Engineering" is a first course for Freshman students intending to specialize in the field, but other students seeking an acquaintance with the discipline also take it. The emphasis is on circuit analysis, both analog and digital, and major objectives are that students will develop an elementary competance in using the laboratory to deal with circuit problems and will begin to learn to solve professional problems that are new to them.

There are two one-hour lectures per week. In addition sections of about 25 each meet once a week for 3 hours in a combination recitation-laboratory room. In subject matter, the course covers electrical quantities (charge, current, voltage), network elements (sources, resistance, transistors, etc.), circuit principles (Kirchhoffs' laws, Superposition, etc.), analysis techniques (e.g., load lines), digital concepts, logic circuit, gates, and flip-flops.

The laboratory experience is designed to complement and be complemented by the material covered in the lecture. Thus the concept of the Thevenin equivalent circuit is vividly illustrated through finding the I-V characteristic of an unregulated power supply, while meter loading is used as the starting point for solving circuits problems.

The highlight of the laboratory experience is a half semester group project. Here each student group (typically 3) is required to decide what is the real problem, plan an attack upon the problem - representing the situation by an idealized model - and decide upon a method, execute the plan, and take stock of what has been accomplished. A final report of professional quality is required.

We find that Freshman students have a wide background in their knowledge of electrical engineering principles and terminology, depending mainly on the amount of hobby work they have had. The laboratory contributes extensively - through group interaction - into evening out the variations by bringing up those who had little past experience to the level of the more seasoned.

We have used digital-based projects very heavily owing to the inexpensiveness and reliability of digital hardware, the ease with which students can relate to digital structured systems - probably because of their grounding in the new math in High School - and to the high sophistication of the end product. The reaction of students to the project experience can be summarized by "I learned a lot during this semester."

Recent projects have been, (1) design and construction of a simulator of the interaction of traffic flow at an intersection with the traffic lights, (2) design and construction of an electronic planimeter, and (3) design and construction of an electronic combination lock. In each case, strict cost limits are placed upon the designs, resulting in products that are quite elegant in conception.

Joint Laboratory Work for Materials and Solid Mechanic Courses

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The Materials Course and the Solid Mechanics Course were taught with a combined, divergent style laboratory supplement. Thermal properties, corrosion characteristics, weathering behavior, fatigue and fracture patterns in conjunction with the chemical and molecular theories of materials is addressed in the sophomore level Materials Course. The Solid Mechanics Course studies the theory and tests the structural properties of materials such as the shear strength, bending capacity, compressive strength and torsional resistance. By combining the laboratory portions of these two courses laboratory assignments consisted of selecting the proper materials in appropriate proportions to meet unusually constrained problems. For the past two years this has occurred even though the Materials Course is taught by the lecture method and Solid Mechanics by PSI. The assignments have been such that interested students could pursue any aspects of the project whether it be in design, fabrication or testing to the level of detail he/she desires. The basic requirements for the laboratory assignments to the class as a whole have been to design, fabricate and test a floor system to carry a 50 lb./sq. ft. load with a 3 hr. fire rating and low frequencies sound insulation and similarly for a hot air solar collector that can fit into a conventional domestic roof system. There was of course additional detail given on the constraints however, no information was given describing appropriate tests for material properties and for properties of the finished product. As part of the laboratory experience the students had to plan and manage their laboratory work, to determine and conduct in accordance with ASTM (or applicable standard tests) tests they determined as applicable to the project, locate and purchase (a budget was given to each project and all purchasing was done with P.O.'s) all materials, and to submit a final product and report. An upper classman in the role of a tutor instructed the students in the use of the equipment, checked all planned testing for safety and graded laboratory work at the time of completion. In using this method the students are faced with a problem, are given the tools to solve it, and are given the opportunity to experience laboratory oriented research as a challenge to be met with imagination, innovation, failures, and hopefully success.

Simulation of Digital Computer Structures

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This Laboratory was used in an undergraduate course designed to teach analysis and design of computer structures. This course follows a one semester course, Introduction to Digital Systems. The laboratory involved a register transfer language (ISPL) which was used to describe an over-simplified mythical minicomputer. The students were given this description and asked to modify and enrich the description by adding features like increased address space, detection of arithmetic overflow and a hardware stack.

In order to simulate the revised computer structure, the students used existing software developed under the supervision of M. Barbacci and D. Siewiorek here at Carnegie-Mellon University. This software includes a compiler for the language (ISP) and an interactive simulator which is driven by the output from the compiler. This software is written in BLISS and runs on a PDP-10 or DEC-20 system.

The advantages of this scheme are numerous. The students could have available a library of ISPL descriptions of computers and digital structures, and can learn a variety of structures in a laboratory setting by programming these computers via the simulator and observing the execution. In addition, the students can modify the "hardware" of a PDP-11, for example, by modifying the ISPL description, and can then simulate the modified PDP-11 to make verification and performance measurements.

INTERACTIVE STUDENT LABORATORY INSTRUCTION

Prof. Frank W. Paul
Associate Professor

Prof. Ranga Komanduri
Assistant Professor

Prof. Wolfgang J. Sauer
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Objectives:

1. To have students learn experimental procedures of testing, including calibration and organization.

2. To enhance student written communication skills.

Discussion:

During the Spring 1977 Semester the authors organized a two hour per week Experimental Analysis course into an interactive student laboratory experience. Four experimental projects were divided into instrument calibration, experimental test, and data analysis activities. Each group of students completed and wrote activity reports. The reports were graded and used as a basis for subsequent group activity.

The experimental projects selected for the Semester were:

1. Tool cutting forces in metal removal (milling machine and lathe).

2. Temperature-time solidification of low melting temperature alloys (cerrolow 117, 136 and woodsmetal).

3. Flow measurement with a rotameter and orifice plate.

4. Force-deformation characteristics of aluminum in compression.

Each class was divided into groups of 3 or 4 students and assigned the initial calibration activity. After completing the activity (2 to 3 weeks) the student groups completed a report. Student groups were then shifted to the next experimental test activity in such a way that they did not work on the previous calibration activity. Written reports from the calibration activity were given to the group conducting the experimental test. The report represented the principal means of communication between activities. Feedback was forced by having groups question and seek information from the previous group. This provided an excellent vehicle for student interaction and communication.

Faculty, in addition to acting as laboratory consultants, provided lectures on experimental procedures and data analysis at appropriate times during the course. At the termination of the course a compendum of the final reports (calibration, experimentation and data analysis) was made available to the students.

Student Planning of Experiments

by
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In the Junior and Senior Chemical Engineering Unit Operations Laboratory courses, the students are required to plan their method of experimentation before they are allowed to perform any of the experiments. The purpose of this laboratory instructional approach is to give the students practice similar to that of industrial procedures. Up to this time in their education the students have been performing cookbook-type experiments. Another advantage of this approach is that it gives the instructor more flexibility in developing experimental problems for the students, because several different experiments can be performed on a single laboratory apparatus.

Our laboratory is operated by assigning several periods for each experiment. The first period is designated as the preliminary report period when the planning is done by the students. During this laboratory period the instructor describes the problem to students and reviews background material needed by the students to perform the experiment. He also describes briefly the operating procedure for the experimental equipment. This information is either given to the students orally or from a cassette tape player. The latter method saves on the instructor's limited office time, and the students have the opportunity to hear the instructions several times. During the latter part of this laboratory period the students write their preliminary report in their laboratory notebooks. These notebooks are given to the instructor to check for completeness and to grade. The students are not allowed into the laboratory until the instructor is convinced that the students know exactly how they are going to perform the experiment. Following the preliminary laboratory period, one to three periods are assigned to perform the planned experiment, and a single period is designated for calculations. The course is designed so that the students can complete the work during the laboratory periods.

Contained in the preliminary report is a clearly defined purpose of the experiment. Following the purpose is a review of the literature. Theories to be demonstrated by the experiment are discussed, and known values of equipment parameters to be determined are described. Next a detailed experimental procedure is written by the students along with a schematic drawing of the equipment. The procedure is not to be written as a numbered list of operational steps. Also in the preliminary report are blank data tables as well as the equations required to be solved. Room for both experimental data and calculated data are to be allowed in these tables. Next in the report follows a list of duties to be performed by each student in a typical three-person group. The last section of the report describes the safety precautions for the experiment. Included are the toxicity levels of the chemicals to be used and symptoms experienced due to overexposure. Safety precautions for operation of equipment must be included. This safety section of the report is included so that the students gain a respect for both the equipment and the chemicals they will be using. Also the students are given a safety lecture at the beginning of the laboratory course.

We believe that planning an experiment before recording a single piece of data is as important as the final analysis of results. Forty percent of the experiment grade given a student is based on his planning effort. We are convinced that improper planning of an experiment can be both costly and dangerous.

Project Laboratories
Stephen L. Rice
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Storrs, Connecticut 06268

The most advanced stage of undergraduate laboratory instruction is the independent project. In such undertakings, students work singly or in small groups to synthesize solutions to real engineering problems. In mechanical design education, project experience constitutes the culmination of a curriculum of courses in analysis and in various discipline-oriented laboratories.

In the Mechanical Engineering Department of the University of Connecticut, a successful senior design project program has been developed. The key to this program is industrial support. Over the past few years, several industries in the state have been visited by faculty, apprised of the goals and structure of the course, and asked to participate. Essentially, industries are asked to provide real engineering problems and financial support. The level of support is modest, requiring only payment for materials and equipment actually used in constructing a system or prototype which solves their problem. Additional support is solicited, following project completion, in a measure commensurate with the success of the design. Thus, a good track record leads to the accrual of "freedom funds". These monies allow the continuation of the project program, and subsidize non-industrially supported projects. The students benefit by working on problems which are realistic and challenging. The project constraints are likewise real, with time schedules of critical importance. Often summer jobs and/or permanent employment opportunities occur as "fall-out", as do consulting opportunities for faculty. Course evaluations from students indicate that this real-world project experience is one of the highlights of the curriculum.

Some of the areas in which recent projects have been completed are listed as follows: mobile audiological facility; institutional wheel chair; tape cable stripper; wire insulation crush tester; wire marking durability tester; wire tension monitor; cold impact tester; wet paperboard handling system; "freeness" measuring device; thrust bearing retainer feeder system; aluminum panel sanding machine; pick and place mechanism; solar hot water system; foam spreader system; copper tape handling fixture; particle aggregation measurement device; and a rotating disc measurement system.

Further information on the program or on specific projects can ben obtained by contacting the author.

"Updating the Undergraduate Electrical Engineering Laboratory"

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Department of Electrical Engineering and Computer Science
University of Connecticut
Storrs, Conn. 06268

1. Integrated-Circuit versus Discrete-Element Laboratory

The increasing use of integrated circuits in electrical design has raised questions about electrical engineering laboratory courses: (1) Should the traditional basic laboratory course using wired discrete circuit elements and active devices be abandoned, since the graduate engineer will hardly ever use them again? (2) How much analog signal processing (AM, FM, etc.) should be taught in view of the trend toward digital signal processing? (3) Should students be compelled to study obsolete technological methods because "It is good for them to know"? (4) How is student interest kept high?

2. At the University of Connecticut these questions are being answered by making a gradual transition toward greater use of integrated circuits in the undergraduate laboratory. Starting in the first semester of electrical engineering laboratory (5th at the University) and ending with a senior project laboratory in the last semester, the division between discrete and integrated circuits is currently as follows:

		Discrete Circuits		Integrated Circuits	
EE Lab.	Semester	Weeks	Topics	Weeks	Topics
A	5	12	Basic	2	Digital Logic
B	6	6	Basic	8	Digital and Analog
C	7	13	Complete Systems	1	Oscillators
D	8	0	-----	14	Student's Project

Electrical Engineering Laboratory C has a textbook written specifically to bridge the gap between theory courses and operating systems as listed below. It devotes one week each to the following systems:

(1) Feedback Control System (mechanically rotated platform)
(2) Coaxial Transmission System
  (a) (fast) Time-Domain Reflectometry System
  (b) Frequency-Domain (VSWR) System
(3) (microwave) Waveguide Transmission System
(4) Antenna Patterns and Impedance (measurement systems)
(5) Spectrum Analysis of Complex (periodic) Waveforms
(6) Oscillator Circuit Design (using integrated circuits)
(7) Radio Transmitting System (AM and FM in time and frequency domains)
(8) FM/AM Radio Receiving System (hi-fi stereo subcarrier spectrum)
(9) Television Receiving System (B&W and color with commercial receivers modified for easy access with an oscilloscope)
(10) (modulatable He-Ne) Laser Optical System (communication link)
(11) Analysis of Human Hearing (booth with audiometer, et al)
(12) Analysis of Human Vision (standard visibility function of color)

The above 13 weeks of laboratory were selected because each is devoted to a system whose use is well known by the student, therefore interest is kept high.

During the first three weeks of the final semester (while preparing a written proposal of his project) the student designs and tests the following integrated-circuit systems:

(1) Active Filters (using integrated-circuit operational amplifiers)
(2) Voltage-to-Frequency Converter (using digital integrated circuits)
(3) Analog-to-Digital Converter (using integrated circuits)

It has been interesting observe that the majority of students elect to continue working with integrated circuits on their projects. The last week of the semester is devoted to a seminar talk and demonstration of each project.

A STRUCTURAL BEHAVIOR LABORATORY COURSE FOR CIVIL ENGINEERING STUDENTS

by Richard N. White, Professor
Department of Structural Engineering
Cornell University, Ithaca, N.Y. 14853

This contribution describes equipment and experiments in a structural behavior laboratory course for undergraduate civil engineering students. The mathematical sophistication achieved by today's engineering student must somehow be complemented by a sound understanding of the basic physical phenomena involved in this particular field of study, and an appreciation of how real structural behavior affects solutions to engineering problems. The laboratory development described here is intended to provide civil and structural engineering students with a significant experience in understanding the complex behavior of structures. It is used in a junior and senior level elective course, and also for an introductory structures concept course at the freshman level.

The basic course begins with simple linear elastic experiments (such as verification of Maxwell's Reciprocal theorem) and progresses through structures exhibiting geometrically nonlinear behavior (buckling of columns and frames; beam-columns) and post-linear conditions involving inelastic material response (the ultimate load capacity of reinforced concrete, steel, and timber members). Students may choose from 8 to 10 different experiments in each of these three categories or even devise his own experiment if he so desires. The course concludes with a project involving some type of structural system (frame, composite bridge, shell, slab system, etc.).

All experiments are done on small-scale structures that can be easily planned and built by the students. Testing is done on stiff tables made of steel bridge decking, with loads applied by hand-operated mechanical jacks reacting against reaction frames made of 4 inch deep aluminum H-sections. Each team of students has a table, strain measuring equipment, dial gages, loading devices, and a complete set of accessories and small tools. Extensive use is made of a special model concrete made of Ultracal 60, sand, and water; the material reaches 3000 psi strength in 24 hours and is ideal for simulating regular concrete in reinforced concrete model structures.

Full details on equipment, experiments and model concrete are available from the author in the Cornell Report No. 346, "Structural Behavior Laboratory - Equipment and Experiments" by R. N. White, 56 pp.

Title of Contribution: Intermediate EE Projects Lab
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This Lab has been taught to all EE's at or near the end of their Junior year. The object of the lab is to provide hand's on experience with equipment related to 4 major stem areas in the EE curriculum. The 4 areas are Electronics (Digital and/or Analog), Linear Systems, Microcomputers, and Logic Design. Three hours credit is given and a typical project in one of the four areas requires about 18 hours of in lab work over a two week period. Each student must complete one of the following options: (1) Four 2 week projects over the stem areas plus one 2 week project in any area of his/her choosing. (2) Three 2 week projects covering 3 of the stem areas plus one 4 week project in the 4th stem area.

The lab does not formally meet for lab work. All lab work is done on an open lab basis with students reserving space and equipment in advance. Sufficient "secure" space is provided to allow each student room to continue a project over an extended period without having to tear it down and begin again the next day. The lab group does formally meet for 1 hour per week for discussion. No formal lecture is given but each student discusses his/her current project, problems, or equipment needs. These sessions often become idea sessions for new projects and become a vehicle for "show and tell".

Students in general work alone - only in rare instances when large projects can be clearly divided do students work in groups. Project ideas are the students responsibility. If a particular student has an idea, he/she writes a brief 1 papagraph description of the work. The instructor reviews this informally and scales the work to fit a two or four week project. Initially students are given a list of project titles and a report from previous projects so that they understand what is expected. In addition, the library is used as a reference station for project ideas. Librarians are coached to provide help and direction.

The lab grade is based on a report which is written for each project. The report is given two grades - one for content which is somewhat subjective but serves as the basis for determining the course grade. The other grade is an advisory grade for English.

Since students must furnish their own lab ideas,they develop an emotional interest in the project and derive satisfaction out of seeing their own ideas come to fruition.

Typical projects have included "A Dissassembler for an 8080 Microcomputer","An 8 Bit D/A Converter from discrete Parts", "Graphical Con volution with Lab Verification", "Comparitive Study of Butterworth and Chebyshev Filters", and "Solution to 2nd Order Differential Evaluations on the Analog Computer."

MECHANICAL ENGINEERING MEASUREMENTS LABORATORY

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The first nine weeks of this 15-week course are concerned with the task of measuring the thrust versus time for a toy solid-propellant rocket engine and, very crucially, determining the accuracy of that measurement. The transducer used is a two-active-arm strain gage bridge mounted at the root of a cantilever beam with the rocket mounted at the free end. Measuring thrust is not new. Such a transducer could hardly be called an innovation. What is different is that the student designs, fabricates, debugs, and calibrates the transducer and its balancing circuit himself. The only "black box" is the oscilloscope which serves to read the imbalance of the bridge. It is in this black box that we put our money. We use research-quality, storage oscilloscopes. The student looks at the oscilloscope and gets the feeling that we really mean business, for this is not a jerry-built, haphazard, anything-goes laboratory class but a place where first-class professional work is done. The student's transducer in effect has to "live up to" the readout equipment to which he connects it.

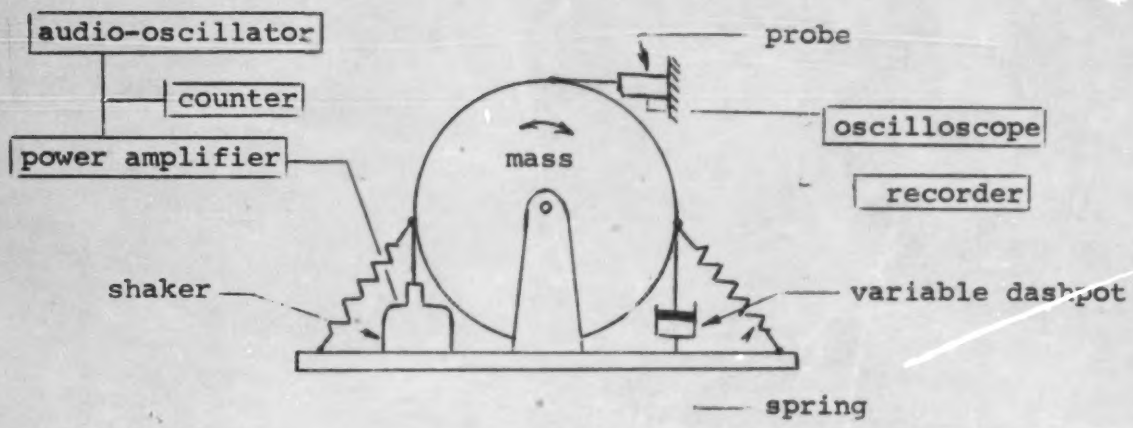
Each week the student is presented with another task related to his transducer. Over a period of weeks he determines how long the cantilever beam should be to give maximum output and yet not yield under the maximum loading expected. He loads the beam to determine hysteresis. He determines the signal to noise ratio and makes various modifications to the circuit to improve the result. Finally he calibrates the transducer, determines repeatibility, drift, linearity, and limits of error, and writes a set of specifications. He is then allowed to fire a rocket to discover that there is a whole area of concern he has overlooked. By providing a chunky, steel mount for the rocket, we have rigged the system so that its natural frequency is about 10 Hz. When a student fires the rocket, he observes a trace on the oscilloscope which he realizes cannot be the thrust-time curve. At this point he is ripe for a review of the fundamentals of dynamics, a measurement of natural frequency of the transducer, and a calculation of the coefficients of the Fourier series that approximates the expected thrust-time relation. Armed with this knowledge, he modifies the transducer by removing the steel mount, cutting excess material off the rocket engine and decreasing the length of the beam, while observing the effect these have on the natural frequency. When the natural frequency of the cantilever is far enough beyond the frequency of the last significant term in the Fourier series, he recalibrates, rewrites the specification sheet and fires a second rocket. This time he has the satisfaction of seeing a thrust-time trace very much like that specified by the engine manufacturer.

What happens after the ninth week depends somewhat on the bent of the instructor. In some cases students are given an opportunity to apply what they have learned to a whole new measurement system, in others the use of a.c. exitation of the bridge is explored, along with the attendant circuit modifications necessary. In some cases it is possible to find enough of interest to spend the entire semester on the thrust-time measurement.

This two-credit course is designed for mechanical engineering students who are in their junior year. The prerequisites are physics through mechanics and electricity, plus calculus through differential equations. Informal weekly reports answer questions which review the previous laboratory work and prepare the student for the next session. Two formal reports summarize major topics.

Dynamic Analysis of a Simple Oscillator

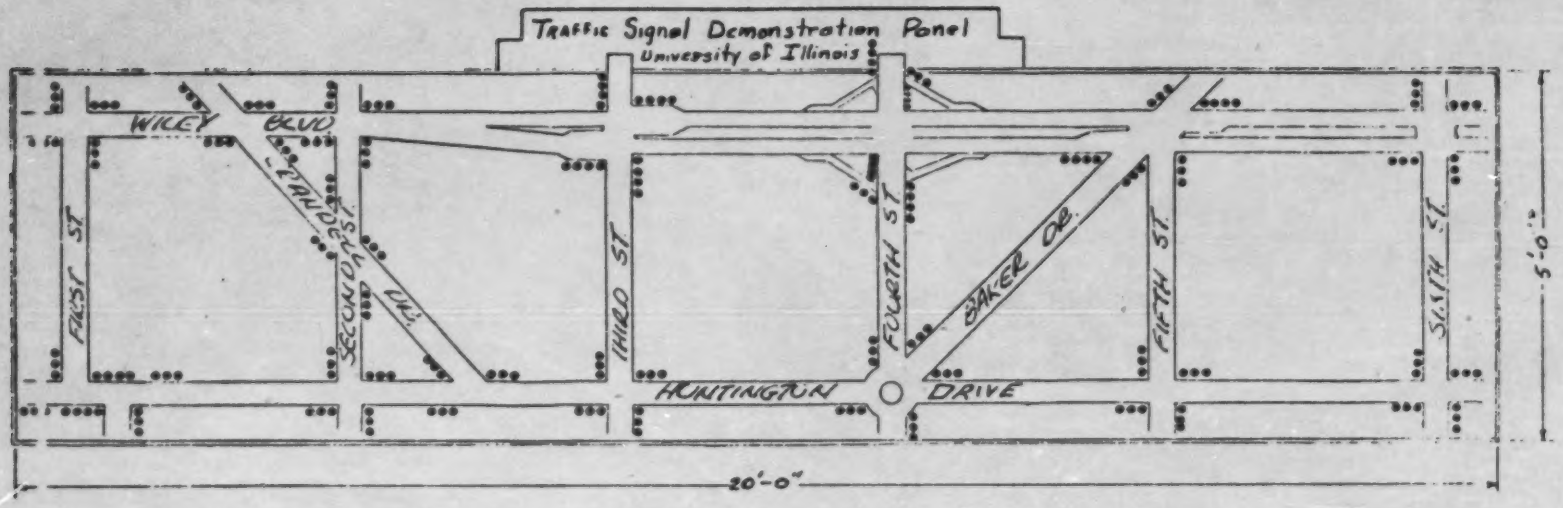
Dr. G. Koopmann, Dept. of Mech. Engr.
University of Houston, Houston, Tx.



The following is a description of a one degree-of-freedom system that has been developed as an experiment in an undergraduate MECHANICS/VIBRATIONS laboratory at the University of Houston. The apparatus is designed to introduce students to methods of analyzing dynamical systems. It is quite versatile and allows for easy alteration of the governing parameters such as mass, spring constant and the damping coefficient. The associated experiments cover several weeks and progress from transient response to forced non-linear response analysis.

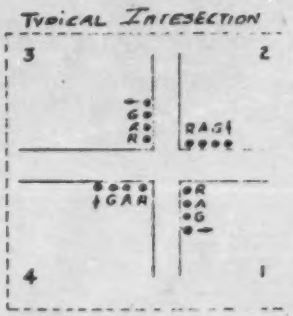
TITLE OF EXPERIMENT	FUNDAMENTALS EMPHASIZED	SUPPORTING INSTRUMENTATION
Damped Free Vibration (transient response)	moment of inertia, spring constant, damping coefficient via decay measurement, damped natural frequency	displacement gages oscilloscope level recorder
Damped Forced Vibration (steady-state response)	damped natural frequency, damping coefficient via half-power point method	audio oscillator counter power amplifier dynamic shaker
Damped Forced Non-Linear Vibration	response of a system with a non-linear spring constant	same as above

Total cost of experiment (excluding recorder) - $1000



Notes:

1. Panel to be utilized in graduate traffic engineering curriculum to demonstrate traffic signal operation at isolated and coordinated intersections. Some intersections to be used to demonstrate semi and full actuation.
2. Layout scale on demonstration panel 1" = 10'.
3. Undivided streets 40' wide.
4. Divided streets 24' wide with 16' median.
5. Blocks normally 400' long.



TRAFFIC SIGNAL DEMONSTRATION PANEL

University of Illinois Traffic Engineering Laboratory
DWG. Scales: Panel Size 1/2" = 1'
Street Layout 1/2" = 120'

* an additional 1.5' has been added to the bottom of the panel

For additional info:
Contact
Professor J. Baerwald

Lecture-Demonstration-Laboratory Courses

Bruce R. Munson, Associate Professor
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Iowa State University, Ames, Iowa

It is sometimes asked whether laboratory courses should be appended to lecture courses or offered as separate, pure-lab courses. For some courses neither of these alternatives is appropriate -- especially when one considers the definition of the word appended: "attached as an accessory or added as a supplement." In a course such as beginning fluid mechanics, for example, I feel that the laboratory experience must be a carefully interwoven, closely correlated portion of the overall course -- a lecture-demonstration-laboratory course.

The only way to adequately understand and obtain a feeling for fluid mechanics is to use an appropriate set of demonstrations and hands-on laboratory experiments coordinated with the lecture material. Two types of non-lecture material include: (1) simple demonstrations that the instructor may use in the lecture portion of the course, and (2) hands-on experiments that the students perform in the laboratory.

The lecture demonstration material should serve as an everyday bridge between the lecture material and the laboratory experiments. Ideally, there would be one such demonstration item per lecture period. By necessity, such demonstrations must be very easy to perform, must not take too much time, and must be inexpensive. Such items must illustrate an idea or principle discussed in that day's lecture, and must do it very simply.

A simple example of such a demonstration item includes the illustration of viscosity by passing around the class two jars filled with fluids -- one with water and the other with 10,000 centistoke Silicone oil that looks just like water. Another example would be to pass around the class a dissected Bourdon pressure gage so that the students may see how it works. The list of such simple examples is limited only by the imagination of the instructor. It is surprising how the student's interest in the material is enhanced by regular use of such items.

The hands-on laboratory experience must correlate well with the lecture material. If the lecture material for one particular week concerns use of the Bernoulli equation, the laboratory experiment for that week should be selected to effectively illustrate the use of the Bernoulli equation. In this way the student will benefit in two directions. Confidence in the theoretical material and a better understanding of the limitations of the theory will be obtained from the experiment. Likewise, the "black magic" of various experimental situations will be better understood in terms of the applications and limitations of the theoretical considerations.

The way to achieve optimum reinforcement of theoretical and experimental considerations is to have a close correlation between the lecture and laboratory portions of the course, with use of numerous simple demonstrations to tie the two portions more closely together. Such requirements specify that the laboratory portion of the course be neither appended to the lecture portion of the course nor treated as a separate course. Rather, the course should be an integrated lecture-demonstration-laboratory course.

Title: Laboratory Assignments for an Introductory Course in Materials Science

Name: Edward M. Mielnik, Associate Professor

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Organization of Course: Two one-hour lectures per week and one two-hour laboratory period per week are required for three semester hours of credit.

The first period of each laboratory assignment is devoted to the presentation of the background material, passing out and going over the duplicated laboratory instructions, and demonstration of the equipment. The second period is devoted to obtaining the bulk of the data. The third period is utilized in obtaining the remainder of the data and/or analyzing it. A balance is struck between a completely structured experiment and an open-ended, student-designed experiment, which is time consuming and taxes the equipment and resources available. The material covered in the laboratory is tied in with the lecture portion of the course. The students are required to write a laboratory report for each laboratory assignment.

The following assignments are performed, which are varied from time to time:

1. Hardness Testing:

Since hardness testing is so important to Materials Engineering, this experiment not only acquaints the student with the various methods of hardness testing, but also allows him to make a fundamental analysis of the significance of the hardness test. The fundamental basis and rationale of indentation hardness are explored by obtaining the coefficient and exponent of Meyer's law, by checking the principle of geometric similitude, and by relating Meyer hardness to the stress-strain curve.

2. Plastic Deformation of Metallic Materials:

The effects of mechanical deformation of various metals are explored by rolling the samples in a small hand-operated rolling mill. The effect of plastic deformation on the stress-strain curve are obtained. The mechanical properties are plotted against the per cent reduction. A number of additional factors may be explored.

3. The Behavior of a Composite Material:

A standard experiment involving the effect of the water/cement ratio on the compressive strength of portland cement concrete are determined.

4. Electrical Properties or Heat Treatment of Steel:

A choice is given of (1) performing an experiment involving the electrical properties of materials in which the electrical resistivity of alloys, the rectification of simiconductor, and the dielectric properties of polymers are determined, and (2) performing an experiment involving the heat treatment and hardenability of steel.

5. Optical Metallography:

This experiment involves the optical metallography of ferrous and nonferrous specimens, in which the microstructure of standard specimens are viewed under the optical microscope and are correlated with colored slides and the phase and/or transformation diagrams.

A number of additional experiments are being planned.

Engineering Physics Lab- Physics of Waves and Electricity.

Gary R. Smith
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Winnipeg Manitoba Canada R3T 2N2

A course on wave physics and electricity and magnetism is given to first year engineering students at the University of Manitoba. Most students are of average ability and background for a publicly supported university, have difficulty applying the mathematical techniques they learned in high school to practical problems, but are highly motivated. A three hour laboratory session, which is associated with the course, meets every week. The first hour of each meeting is devoted to a problem solving session and the last two hours are to laboratory exercises. The laboratory exercises are closely coordinated with the lecture content of the course, so that fundamental ideas are illustrated in the lab within a week or two of their introduction in lectures.

The basic goal of the laboratory is to provide the students with a common set of experiences designed to develop 1) their ability to apply mathematical techniques to the solution of practical problems. 2) their powers of observation and physical intuition. 3) their ability to make reproducable measu rements. 4) Their appreciation of the errors made in making those measurements. and 5) their ability to communicate the results of their experiments to others. To accomplish these ends, three different types of exercises are used. First, mathematical and graphical exercises are performed with emphasis on displaying results in an aesthetically pleasing fashion. Secondly, to help develop physical intuition, exercises are presented where qualitative observations are made of phenomena as various parameters in that exercise are changed, with the results being described in written form. Finally, actual experiments are completed which require the measurement of a specific quantity and the error associated with that measurement. After each days exercise the student writes a four or five sentence abstract summarizing their day's tasks. Each year the student writes two formal reports on some aspect of his work. This student work is supplemented by demonstrations performed by instructors, using modern equipment, where, for reasons of cost, only one experimental setup is available.

The laboratory is operated by one experienced staff member and one graduate student demonstrator for each two hour period for aproximately sixty students. A high degree of instructor student interaction is maintained, ensuring that each student has a high probability of successfully completing each exercise. While equipment has been purchased for the exercises, all the experiments we present have been developed at the University of Manitoba. Furthermore, we set a goal of revising about 1/3 of our presentations each year to keep a constant program of revitalization in force. We expect a high standard of performance from each of the students we contact in this laboratory.

The Great Beer Bottle Experiment (or How to measure the speed of sound using a cylindrically shaped Helmholtz resonator.) *

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We describe a low budget experiment, using materials readily availible, to measure the speed of sound with an error of less than 5%. The device consists of an Helmholtz Resonator of cylindrical cross section (a standard 12 oz beer bottle). The system is analogous to a mass vibrating on a spring. The resonant frequency is determined by the mass of the plug of air located in and near the neck of the bottle and the spring constant associated with the elasticity of the air filling the remainder of the bottle. A simple procedure involving length measurements made with a vernier calipers is outlined and a discussion of the approximations made in arriving at this procedure is presented. The result of this experiment provides the explanation for the musical note that can be produced when one blows across the open end of a bottle.

The experiment requires two bottles, one to act as a resonator, and the other to act as a fluid reservoir, a set of four or five tuning forks to stimulate oscillation of the system (frequency range 250-1000 hz), a vernier calipers to measure lengths and about one half metre of aquarium tubing to use as a siphon between the reservoir and the resonator.

The angular frequency of a mass vibrating on a spring is given by

$$k/m,$$

where k is the spring constant, in this case supplied by the elastic properties of the gas in the body of the bottle and m is the mass of the vibrating air plug. If the volume of the air plug is v then its mass is given by v, where is the density of the gas in the plug. The spring constant is calculated from the pressure exerted on the cross sectional area of the neck, a, and is related to a change in volume of the gas in the remainder of the bottle through the compressibility of that gas. The speed of sound is introduced through its relationship with the compressibility of the gas. An equation relating the angular frequency with the speed of sound and the above mentioned variables and the volume of the remainder of the bottle, V, is obtained:

$$\frac{k}{m} = \frac{a^2 c^2}{v V} \quad .$$

This is reduced to an equation relating the depth of the liquid in the bottle, below the top of the neck, L', the effective length of the neck, , and the area of the bottle, A, of

where we have replaced by 2 f.

A siphon is established between the two partially filled bottles using the quarium tubing. A tuning fork is struck and held over the mouth of th[e] resonator. As the level of the liquid passes through the value for resonance a sharp increase in intensity is heard. The depth of this level is measured with the vernier calipers.

* To be published in American Journal of Physics

STRUCTURAL MATERIALS LABORATORY: A Laboratory Course for Engineering Undergraduates at the University of Miami

The objectives of the Structural Materials Laboratory are designed primarily to serve two important functions. First, to demonstrate and reinforce the physical principles enunciated in other courses of the engineering curriculum. Secondly, to introduce students to elements of the art of engineering communication and testing procedures. With these goals in mind a broad ranging, closely supervised, course syllabus is utilized. A laboratory manual giving a brief theoretical background as well as a detailed description of each experiment is used in connection with lectures and demonstrations.

Ideally students conduct experiments in a hands on fashion in groups which are small enough for the instructor to assist "in loco". A group of three experiments are conducted during one class period for demonstration, and for the next three class periods each group will independently undertake each experiment on a rotating basis. After this period another three experiments are discussed and demonstrated and the process is repeated. The instructor and an assistant are available during each laboratory session for assistance as needed. Experiments are designed to demonstrate principles of structural mechanics; St. Venants principle, buckling, notch sensitivity, etc., as well as materials testing. Modern techniques involving strain gage instrumentation and autographic equipment are employed.

While student groups are formed of at most 5 students, many experiments require inter-group cooperation to gather enough data to apply statistical analysis in its interpretation. However, laboratory reports are independently submitted even though much of the data may be shared.

Techniques of engineering communication are stressed in report writing. Grading is based heavily upon progress in the development of communication skills which each student demonstrates during the semester. The student is encouraged to utilize tables, charts and graphs in presenting the most information with a minimum of report volume.

By the end of the semester each student has been involved in nine experiments. Materials including metals, concrete, and wood, are tested under static and dynamic conditions, carefully varying modes of loading, environmental conditions, etc. It is intended that the students will benefit from the experience of the hands on laboratory and also appreciate the requirements of the engineering communicative process.

For additional information, contact Professor T. Watts

A TANDEM-COURSE OFFERING IN TECHNICAL DESIGN AND COMMUNICATION

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Methods are always needed for improving the simulation of the professional engineering situation in project (design) courses. We are exploring ways to bridge the gap between the teaching of the technical and communicational aspects of engineering. Classically, "engineering" is taught in engineering courses and "communication" is taught in rhetoric courses. Yet this approach ignores the fact that technical communications are received, and evaluated, holistically in the professional world. More importantly, it fails to exploit the fact that the two disciplines share critical features:first, a problem-solving methodology, and second, a common goal of product instrumentality. Whether the product be "paper" or "hardware," students need ultimately to be challenged to produce results of professional caliber, that is, of engineering significance and social consequence. The tandem courses described below, through which credits are earned in both technical design and communication, address these needs.

The tandem courses begin with an examination of the problem-solving methodology underlying the arts of "engineering" and "communication"; problem definition is in fact the focus of an initial series of joint presentations. Moreover, an integrated approach is taken in the instructional phases whenever possible: Joint presentations are also made, for example, on such topics as solution methodologies, information accessing, and audience analysis. The examples used to illustrate rhetorical principles are drawn largely from the technical subject addressed in the courses. Written and oral communication "assignments" deal exclusively with project efforts. More importantly for simulation of a professional situation, all reporting has instrumental value: Letters of inquiry are written to elicit information needed for the project; oral presentations are made during information-exchange activities with professionals working in the project problem area. Furthermore, like professionals, our students must respond to contingencies: For example, requests for information on the project are handled by them on an impromptu basis.

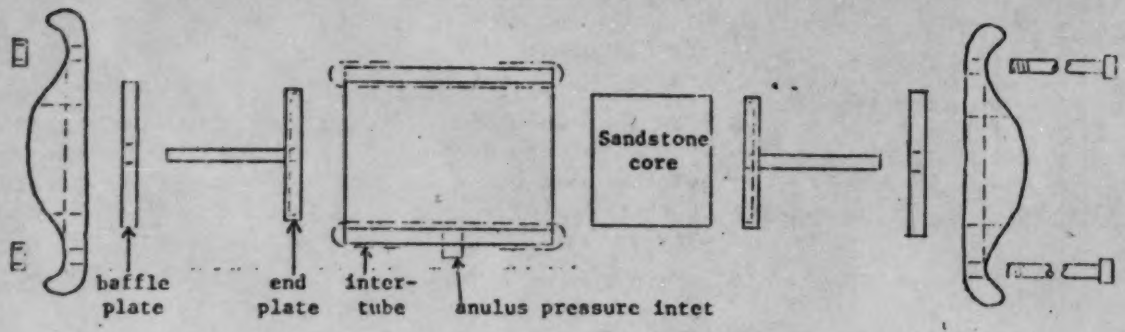
In later phases of project design activity, too, we aim at fostering professionalism, at developing more marketable skills, among the students involved. Designs are subject to stringent criteria: To ensure that hardware designs reflect sound engineering judgments, the question "Will it work?" is addressed through direct experimentation; both high cost-effectiveness and broad marketability are sought in project products. As a further guage of professional merit, project results are submitted to engineering journals, contests, and potential sponsoring agencies of follow-on hardware projects.

A brief comment on the choice of project problem area. Aid systems for the handicapped have proven a particularly viable vehicle for cultivating professional skills. The state of the art in aid systems is such that significant contributions to the field can be made by a student project group. Additionally, aid-system design problems involve a complex of issues--medical, social, communicational, economic, political, psychological, and technological in character. With such problems, we avoid one of the pitfalls of many classroom exercises, namely, the oversimplified--and therefore unprofessional--treatment of problems resulting from atomistic context-free approaches.

TWO PHASE FLUID FLOW IN A POROUS MEDIA

Herbert Warren
Associate Professor of Petroleum Engineering
Mississippi State University

A regular four inch pipe connection sleeve and a motorbike tire tube were used to construct a Hassler Sleeve. Three inch diameter end plates were constructed of stainless steel to fit on both sides of a three inch diameter berea sandstone plug. The sandstone plug was cut to a length of 2 1/2" to 2 3/4" inches.



The apparatus was assembled. The end plates were fitted snugly against the core and an anulus pressure of 35 psig (plus) was applied with a pressure regulator to seal the tube against the end plates and core. The baffle plates restricted the anulus pressure to the interior of the sleeve.

Two tanks hooked up in parallel with appropriate valves were connected to one end of the sleeve. A regulator from the laboratory was used to flow air through the core at different pressures up to within 5 psig of the anulus pressure. The Klinkingberg Effect of gas flow was demonstrated and the permeability of the core to gas flow was determined.

One tank was filled with distilled water and the other tank was filled with diesel fuel. A vacuum was applied to the sleeve and the core was saturated with water. With water only flowing, the permeability of the core with a one phase fluid saturation was determined and compared to that found with air.

The water flow was stopped. Diesel fuel was allowed to flow and partially displace the water until only diesel fuel flowed through the core. The relative permeability to diesel fuel flow in a two phase system was determined.

The diesel fuel flow was stopped. Water was flowed through the core until only water flowed and the relative permeability of water was calculated and compared to its permeability at 100 percent saturation.

Other variations of two phase flow are possible. The apparatus may be used to construct relative permeability curves of a two phase saturation system.

IN SITU COMBUSTION OF OIL IN SAND

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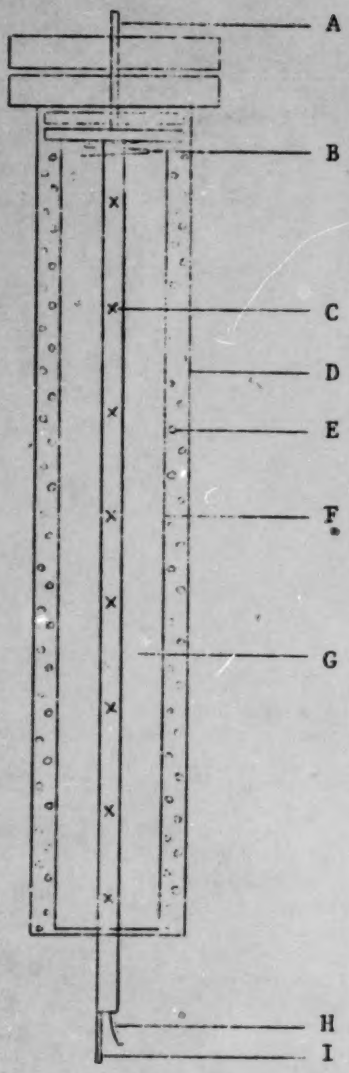

The purpose of this experiment is to demonstrate the recovery of heavy crude oil from deep reservoir rocks by burning part of the oil to create heat to lower the oil viscosity and reservoir energy to push the oil from the reservoir.

Clean sand, heavy oil, and water are carefully weighed and measured. Sand and water are mixed in precise amounts. Oil is added to the mixture. The oil and water saturations are calculated.

A known weight of the mixture is tightly packed in a burn tube about four inches in diameter. A small tube with eight thermocouples is located in the center of the burn tube at equal intervals to measure temperature. The tube is sealed in place in a pressure chamber and packed with insulation.

The bottom valve of the burn tube is opened and any excess oil collected in the bottom is drained and measured. If no oil drains or after drainage ceases, a high pressure air source is connected to the top of the burn tube and the pressure chamber. Pressure inside and outside the burn tube is equalized. Air is forced through the burn tube at room temperature to drive out any excess free oil not previously gravity drained.

An electric heater in top of the burn tube is heated to about 1000° F to ignite the oil while air is forced through the tube. The products from the bottom of the burn tube are separated and the oil, water, and gaseous products are measured.

The burning front position is monitored by the thermocouples.

When the burning process is completed, the volumes of produced oil, water, and gasses are measured and compared to the amount placed in the tube. From this a material balance is derived and the displacement efficiency of the insitu-combustion of oil is calculated.

(A) Air Inlet
(B) Electric Heater
(C) Thermocouple
(D) Pressure Cell
(E) Insulation
(F) Burn Tube
(G) Oil Sand-Pack
(H) Thermocouple Wires
(I) Outlet Tube

BASIC SIGNAL CHARACTERISTICS AND THEIR MEASUREMENT

by

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Course: Required junior ME Instrumentation and Measurements Laboratory

Objectives: To familiarize the student with: 1. The basic types and characteristics of signals; 2. the use of common instruments to measure the resulting electrical signal; and 3. how to interpret the instrument indications based upon a study of an instrument's components.

Equipment: 1. Cathode Ray Oscilloscope (CRO); 2. Analog Volt-Ohm-Milliameter (VOM); 3. Digital Multimeter (DM); 4. Function Generator with DC offset; 5. RCA Analog VOM demonstrator (a VOM with circuit components conveniently accessable and labeled).

Procedure:

1. Instruments, Their Components and Characteristics: The student begins by viewing a video tape describing the components of a VOM and how the electrical signals are processed. An RCA VOM demonstrator is used with an oscilloscope to demonstrate: the rectification of a signal when the meter is on the AC scale, the inability of the meter when set on DC to follow rapidly varying signals thus indicating the average value of a signal, and the AC scale form factor by sending a known constant input voltage into the analog VOM set on the AC scale. A second tape describes the operation of a CRO and leads the student through a series of basic measurement operations using the various scope controls and the function generator as a voltage source.

2. Measurement of Signal Characteristics and Interpretation of Indicated Values:

2a: The student is asked to measure an unknown signal with the CRO, VOM and DM. A typical signal which has been used is $2 + 2 \cos(2\pi\ 300t)$. First, using the CRO, the signal is sketched with the mode control alternately set on Ground, DC to observe the entire signal, and AC to observe the removal of the DC component. From the sketch, the student calculates and records such signal characteristics as the AC component, DC component, RMS value, RMS value of only the AC component, the period and frequency, and the equation of the signal.

2b: The signal is next measured with the analog VOM set on the DC scale. The student has previously learned in Part 1 that the D'Arsonval movement is unable to follow a rapidly changing signal and tends to indicate the average (DC) value. This fact is verified by comparison of the indicated voltage to the DC component determined with the CRO.

2c: The student then measures the signal with the VOM set on AC. Since the unknown signal has a (positive DC offset) $\geq$ (the sinusoidal amplitude), the rectified signal is the same as the original and the indicated value is equal to the (DC component times the form factor). Comparing the indicated voltage to the signal characteristics previously calculated using the CRO, the student finds no correspondence. Thus the caution which must be used when interpreting the voltage indicated by a VOM on AC when measuring a signal other than a pure sinusoid is emphasized.

2d: The above procedure is repeated using the DM. When on DC, the student observes the sampling characteristic of digital meters due to the continuously changing and random voltage displayed. When on AC the indicated voltage is not the same as indicated by the VOM and after comparing it to the signal characteristics calculated from the oscilloscope, the student should recognize it as the RMS value of the pure sign wave component. He thus realizes that this particular multimeter removes the DC component before rectification.

CROSSBREEDING INSTRUCTIONAL TECHNIQUES FOR EFFECTIVE LABORATORY INSTRUCTION

by

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As described in this compendium, various instructional techniques have been crossbred to effectively instruct a sequence of two required junior level Mechanical Engineering Instrumentation Laboratories. The integration of teaching techniques has evolved over the past eight years due to: 1. diverse background experience of students with instruments; 2. rapid technical advances in instrumentation; 3. need to more effectively utilize high quality costly equipment; 4. large number of students (up to 73 per semester); 5. the need to create confidence with hands-on experience with industrial quality equipment; and 6. the need for course transportability to the Kansas City Campus.

Semi Self-Paced: The course content is subdivided into (1 1/2) to (2) week segments. At the beginning of each segment the students meet as a class to receive instructions, modules, a brief demonstration of the experiment and a survey of related instruments and manufacturers literature. Also since lab reports on a segment are due approximately one week after a segment, questions over the prior experiment are discussed. During the remainder of the segment, students at their own pace work the modules, perform the lab and write their lab report.

Interactive Modules: Interactive modules are used in place of lecture. The modules consist of pretest questions, body (containing intermixed discussion and sequence of questions allowing students to interact in the derivation of mathematical models, determination of sources of error, etc.) and a set of answers to questions.

Self-Scheduled Labs: The class is divided into lab groups with no more than three people. The experiment for a segment is available for a two week period. For each experiment, student groups schedule their two hour lab performance at a time compatible with their weekly agenda.

Video Taped Lab Instructions: The instructions for the experiment (calibration, control settings, explanations, demonstrations, data reduction, etc.) are given using a cassette video playback unit. A lab assistant or instructor is available to answer questions if problems arise.

Single Lab Set-up with Commercial-Research Instrumentation: After each two week segment the single experiment set-up is dismantled so that the instruments can be used in other experiments, courses or research. Through this arrangement a balance is being reached between individualized opportunities for students, high utilization of equipment and focusing available resources on modern professional quality instrumentation.

Transportability: The use of modules and video tapes has greatly aided the teaching of the equivalent laboratory courses in a new engineering program on the Kansas City Campus. Also, some equipment is shared between campuses. Chemical engineering on the Columbia Campus has also utilized four of the experiments and related modules.

Lectures-Tests-Grades: Two, two hour periods are scheduled per week. Only part of these periods are used as needed to introduce the next segment, give tests, answer questions and give help sessions as requested by the students. Grading is based upon an adjusted percent of the total points accumulated from three two hour exams and nine to ten lab reports per semester.

FORCE AND MOMENT COMPONENT MEASUREMENT

by

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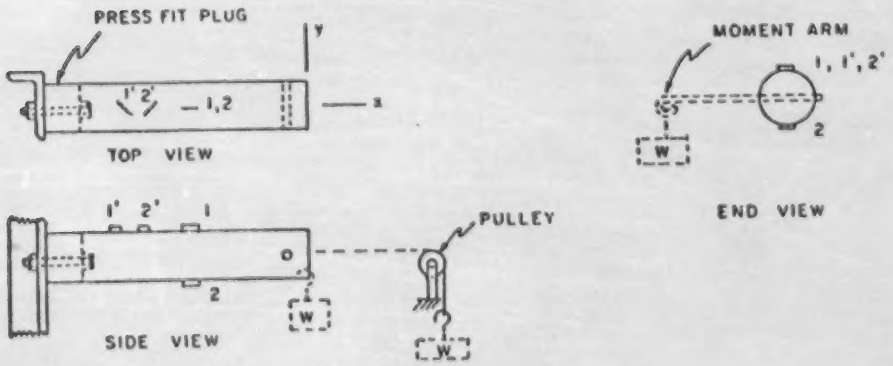
Course: Required junior ME Instrumentation and Measurements Laboratory

Objectives: 1. Teach the concepts of: load cell design to measure a scalar component of a force or moment, and "cross sensitivity" to the other components.
2. Provide experience designing, connecting and utilizing bridge circuits sensitive to equal, and to equal but opposite "sign" strains.

Equipment: 1. Two Daytronic model 300D transducer amplifier-indicators with type 90 strain gage input module; 2. One inch copper tubing 50 cm long with 3 cm steel plug press fit in one end for attachment to form a cantilever; 3. Four strain gages, two located at $\pm$ 45° to the tube axis and two paralled to the axis; 4. 30 cm torque arm; 5. 60N weight; 6. Low friction pulley on ring stand; 7. 3 cm square copper sheet with four temperature compensating gages. All gage lead wires are 1 m long with banana plugs for easy bridge connection.

Procedure: 1. Connect gages 1 and 2 to one Daytronic to form a non-adjacent arm bridge and load cell primarily sensitive to axial force F_x.
2. Connect gages 1' and 2' to the other Daytronic in adjacent legs to form a load cell primarily sensitive to axial moment M_x.
3. Check the design and cross sensitivity by creating the following loads.
   a. F_x by connecting the loop in one end of the string to the torque arm and hanging the weight over the pulley.
   b. F_z by hanging the weight on the end of the tube.
   c. F_z with M_x by hanging the weight on the end of the torque arm.

Theoretical Calculations:
1. Derive equations for the strains in gages 1, 2, 1' and 2' for the three modes of loading to determine if $\varepsilon_1 = \varepsilon_2$ or $\varepsilon_1 = -\varepsilon_2$, etc.
Note, for gages 1' and 2' with (F_z and M_x loading) $\varepsilon_1' = \varepsilon_F + \varepsilon_M$ and $\varepsilon_2' = \varepsilon_F - \varepsilon_M$ where ε_F is due to F_x and ε_M is due to M_x.
2. Derive equations for the bridge output voltage for each type of load to prove if the bridge is or is not sensitive to the force-moment components. Note that the bridge containing gages 1' and 2' will only indicate the equal and opposite component ε_M for (F_z and M_x) loading.
3. Make numerical calculations of strains for which the bridges are sensitive and compare theoretical to experimental results.



IMPEDANCE SPECIFICATIONS AND LOADING ERROR

by

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Course: Required junior ME Instrumentation and Measurements Laboratory

Objectives: 1. Define loading error; and source and load impedance.
2. Use impedance specification to minimize loading error.

Equipment: 1. Simpson VOM model 260; 2. Tektronix digital multimeter model 501; 3. Resistor board with two 2K resistors in series and two 100K resistors in series; 4. Dry cell.

Procedure: Typical results of the following procedure are handwritten in Tables 1 and 2.

1. Experimental Measurement:

For the circuits shown in Table 1, calculate the open circuit voltage V_{AB} and then measure it with each voltmeter using the range settings given.

Table 1: Experimental Data

	Theoretical V_{AB}	Simpson VOM Range Setting	Simpson VOM V_{AB}	Tek. DM Range Setting	Tek. DM V_{AB}
A. Dry Cell, B, A		2.5	1.59	2	1.56
		10	1.59	20	1.64
B. Dry Cell, 2K, B, 2K, A	0.8	2.5	0.76	2	0.78
		10	0.75	20	0.81
C. Dry Cell, 100K, B, 100K, A	0.8	2.5	0.38	2	0.77
		10	0.60	20	0.81

2. Use of Instrument Specifications to Predict Results:

Record the following in Table 2.

a. Calculate the Thevinin equivalent source impedance R_S for each circuit.

b. From specification sheets for each voltmeter determine its load impedance R_L.

c. Calculate the % loading error as indicated in Table 2.

Table 2: % loading error

	R_s	R_L	Theoretically*	Experimentally**
Circuit B				
a. VOM 2.5 V range	1000	50,000	1.96	5
b. DM 2 V range		10×10^6	0	2.5
Circuit C				
a. VOM 2.5 V range		50,000	50.0	52.5
b. VOM 10 V range	50,000	200,000	20.0	25.0
c. DM 2 V range		10×10^6	0.49	3.75
d. DM 20 V range		10×10^6	0.49	1.25

* Using the equation $(E/R_L)/(1 + (R_S/R_L)) \times 100$

** Using the equation $((V_{FM} - V_M)/V_{FM}) \times 100$

INTRODUCTION TO ACOUSTICS AND THE MEASUREMENT OF SOUND

by

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Course: Required junior ME Instrumentation and Measurements Laboratory

Objectives: To introduce students to: 1. the physical and psychoacoustic aspects of sound. 2. The measurement of sound pressure level and spectral analysis of sound.

Equipment: 1. Two function generators (one with DC offset capabilities); 2. Radio amplifier and wide band speaker; 3. GR type 1564-A Sound and Vibration Analyzer; 4. Sound level meter; 5. Tektronix 7L5 spectrum analyzer connected to XY plotter; 6. Oscilloscope.

Procedure:

1. Experiment 1: The first experiment involves generating a 75 phon equal loadness counter for each student to demonstrate the characteristic frequency response of the human ear. To accomplish this one function generator is connected to the amplifier speaker system and the oscilloscope (for visual observation of physical changes in the sound). A student is seated about 3 meters in front of the speaker and with the microphone of the sound analyzer near his ear. A 1000 Hz 75 db sound pressure level, SPL, (indicated by sound analyzer set on all-pass) is generated as the reference tone. The student then adjusts the function generator to another frequency and without looking at the sound analyzer he adjusts the amplifier gain until this tone sounds as load as the reference 1000 Hz tone. He then records the corresponding SPL from the sound analyzer. After repeating the above steps for 5 or more additional frequencies in the audible range, each student is asked to plot his lab groups data on a copy of Robinson and Dadson's equal loadness contours for pure tones.

2. Experiment 2: In the second experiment a 75 db SPL, 100 Hz tone is measured using a sound level meter sequentally set on the A,B, and C weighting scales. The results are theoretically predicted by using the meter frequency response waves as specified in the USA standard for sound-level meters. This illustrates the effect of the weighting scales and use of frequency response curves to predict output.

3. Experiment 3: The two function generators are used in series to generate a sound consisting of the sum of known amplitude 300 Hz and 3000 Hz components. The signal is viewed on the oscilloscope and then analyzed using the sound analyzer set on one third octave band pass. The center frequency is adjusted sequentially from below 300 Hz to above 3000 Hz and SPL readings are taken and plotted at each frequency to produce a sound spectrum. Students are asked to add the two highest sound pressure level readings (center frequencies 300 Hz and 3000 Hz) and compare this to the all pass SPL indicated by the analyzer. Students are asked to provide reasons why the sum does not equal to the all pass to get them introduced to non-ideal filters, etc. They are also asked to calculate the sinusoidal amplitude ratio A_2/A_1 from the decibel sound pressure levels. The Tektronix 7L5 analyzer and XY plotter is used to analyze the signal to introduce students to commercial real-time analyzers.

LINEARITY, HYSTERSIS AND LEAST SQUARES CURVE FITTING

by

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Objective: 1. To illustrate the meaning of hystersis and linearity specifications.
2. Apply the "least squares" technique of curve fitting.

Equipment: 1. Pendulum; 2. Single turn potentiometer; 3. Digital voltmeter; and 4. Dry cell battery.

Procedure: The experiment is set up by connecting the battery and potentiometer to the DVM as illustrated in the figure below. The shaft of the pendulum is connected to the shaft of the potentiometer by Tygon plastic tubing with axial cuts or slices to increase hysteresis.

Voltage readings are taken as a function of the position of the pendulum by moving the pendulum to 50°, 30°, 0°, 30°, 50°. This is done three times by approaching the angle from the positive direction and similarly three times from the negative direction.

Data Reduction:

1. Calibration points of indicated voltage as a function of angle are plotted using mean values of the three readings for each angle as approached from the positive direction. Also points for the readings approached from the negative direction are plotted and the student is requested to calculate the maximum value of hysteresis.

2. On the same graph, a least squares straight line of the ten mean values of the data points is plotted. Then the experimental ±y% FS (Full Scale) linearity-hysteresis specification of the system is calculated, and the corresponding lines are drawn on each side of the least squares calibration curve. Also, the lines corresponding to the linearity specification given by the manufacturer of the potentiometer are drawn to determine if the hysteresis observed is entirely due to the potentiometer. The ±y% FS linearity-hysteresis lines resulting from the potentiometer specification should fall within the experimentally determined lines of the pendulum-coupling-potentiometer system. Therefore the student is asked to determine what other sources of hysteresis exist and hopefully conclude that it is the flexible coupling.

MEASUREMENT OF ANGULAR DISPLACEMENT AND HIGH SPEED PHOTOGRAPHY

by

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Course: Junior level required ME Instrumentation and Measurements Laboratory

Objectives: To demonstrate: 1. two methods of measuring the angular displacement of a pendulum (high speed photography, and a potentiometer-recorder system); 2. the relative ease of set-up and data reduction; and 3. the relative loading effects of the two measurement techniques.

Equipment: 1. Precision potentiometer and pendulum system; 2. Polaroid camera and tripod; 3. Stroboscope; 4. Strip chart recorder.

Procedure:

1. Photographic record without potentiometer attached: The linearized differential equation of motion for the pendulum shown below is derived in order to estimate the period of the pendulum motion. A flash rate for the strobotac is then calculated so that the pendulum moves through an angle of approximately 10° between flashes (10 film exposures per half cycle if released at +50°). The camera shutter speed is set tc be open for slightly more than the first half cycle. The room is then darkened and the pendulum is illuminated with the strobe. The shutter is open, then the pendulum is released from rest at θ=50°, and thus obtaining a photographic displacement-time record. From the photograph a graphical plot is made of angular position as a function of time.

2. Photographic record with potentiometer attached: The above procedure is repeated after first attaching the pendulum shaft to the potentiometer, thus illustrating the effect of potentiometer friction on the displacement-time record.

3. Strip Chart Record Using the Potentiometer: The potentiometer, still connected to the pendulum, is now connected to a battery and strip chart recorder. The recorder-pot system is calibrated and a record is made of the motion of the pendulum after being released from rest at θ=50°.

The student is asked to compare the two methods of measuring angular displacement with respect to: 1. ease of set-up and data reduction and 2. loading effects of the measurement system on the measurand.

SELECTION OF RECORDERS TO MEASURE DYNAMIC SIGNALS

by

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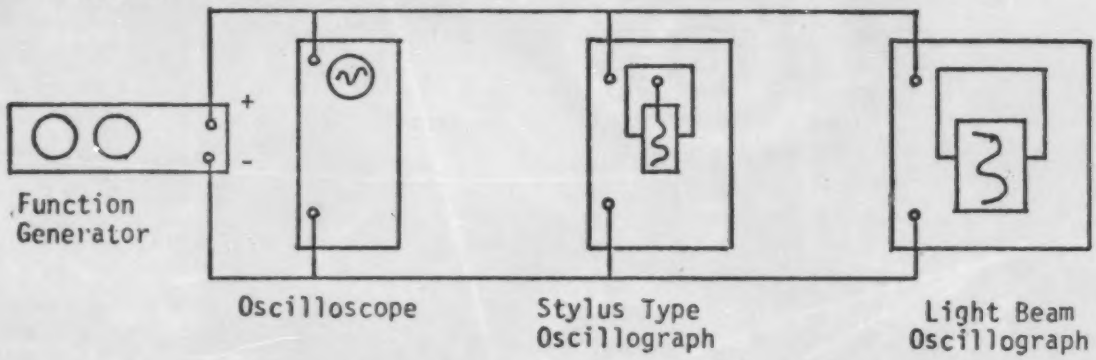
Course: Required junior level ME Instrumentation and Measurements Laboratory.

Objective: 1. To experimentally determine frequency response characteristics of several types of records. 2. To illustrate the importance of frequency response specifications in the selection of instruments to record dynamic signals.

Equipment: 1. Two function generators (one with external DC offset capabilities); 2. Oscilloscope; 3. Stylus oscillograph; 4. Light beam oscillograph.

Procedure : 1. Experimental Determination of Frequency Response: The same sign wave signal is fed into each recording device by connecting them in parallel with a variable frequency function generator. The frequency of the generator is initially set at 4 Hz and the gain of each recorder is adjusted to produce a convenient amplitude, A_4, (e.g. 20 divisions peak to peak). The function generator is then incremented to 6, 10, 30, 200, 300, 400, 600, 10,000, and 100,000 Hz and the output magnitude, A_i, indicated by each device is recorded for each frequency. A plot of amplitude ratio ($M_i = A_i/A_4$) as a function of frequency for each recorder is made. The students are asked to plot the $\pm$10 db lines and determine a ($\pm$ 10 db, ?$\leq w \leq$?) specification for each instrument. They are also asked to investigate how the manufacturer of the recorder specified the frequency response, compare it to theirs and also indicate on their plot the specified resonant frequency if given by the manufacturer.



2. Use of Frequency Response to Select a Recorder: The second function generator is connected in series with the first to generate a signal ($v_{input} = A_1 \sin w_1 t + A_2 \sin w_2 t$). The students are asked to predict each recorders output ($v_{output} = M_1 A_1 \sin(w_1 t + \phi_1) + M_2 A_2 \sin(w_2 t + \phi_2)$) by determining M_1 and M_2 from their experimental frequency response curves. w_1 used is low enough such that $M_1 = 1.0$ for all recorders. w_2 is at a higher frequency such that M_1 is approximately equal to 0. .6 and 1.0 for the stylus, light beam and oscilloscope respectively. Then the signal is recorded with each recorder, and students are asked to compare theoretically predicted and actual amplitude for each component of the sine wave for each recorder. The students are also asked to predict phase angles ϕ_1 and ϕ_2 from theoretical phase response curves for a second order system.

UNBALANCED SHAFT DETECTION BY SPECTRAL ANALYSIS OF VIBRATIONS

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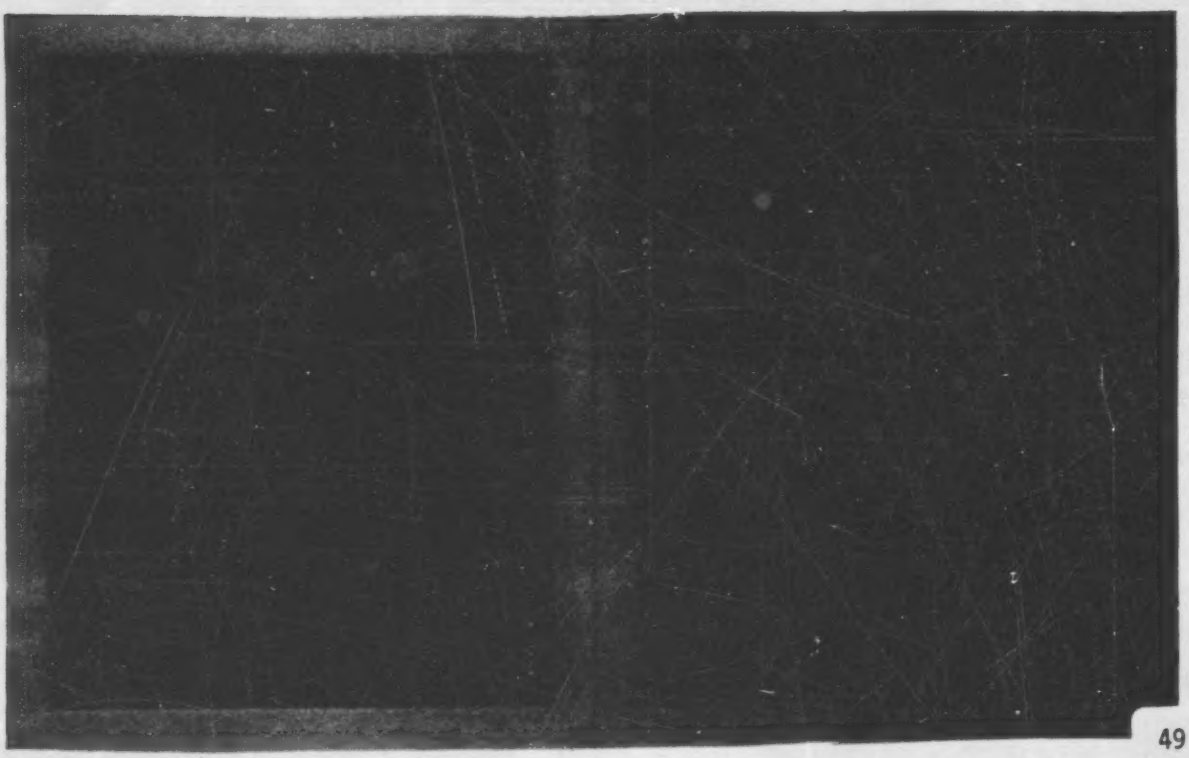
Purpose: To demonstrate the use of spectral analysis as a machine diagnostic tool (in this example detection of which shaft is unbalanced).

Equipment: 1. Tektronix 7L5 spectrum analyzer; 2. Accelerometer and charge amplifier; 3. Tachometer (photocell); 4. Air motor capable of 10,000 rpm; 5. Gear box with four shafts turning at different speeds with a removable unbalanced weight; 6. Oscilloscope; 7. XY plotter.

Procedure: Unknown to the students, the unbalanced weight is attached to one of the four shafts and the gear box is sealed. The students are asked to determine, without opening the box, which of the shafts has been unbalanced. The accelerometer is connected to the gear box to detect its vibrations. The signal from the accelerometer-charge amplifier system is observed on the oscilloscope. No conclusions about shaft unbalance can be made from the scope due to the highly noisy signal. Therefore, the signal is fed into the spectrum analyzer which produces a spectrum with four distinct spikes (plus a spike at 0 Hz), the highest amplitude one corresponding to the purposely unbalance shaft. The associated frequency (shaft speed) of the tallest peak is read from the analyzer. Using the tachometer the students next measure the four shaft speeds to determine which one is rotating at the unbalanced shaft speed as predicted by the spectrum analyzer. The XY plotter is used to produce a hard copy of the spectrum for the students lab report.



Back To The Old - Or Is It?

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In 1969 the Department of Electrical Engineering at the University of Missouri-Columbia instituted a new curriculum which was quite radical when compared with the old. Two features are illustrative of the difference. One was the increase in flexibility for developing a curricular package and the other was placing all laboratory instruction into a three, three credit course sequence. Course I was concerned with measurement theory and technique, learning to use basic laboratory equipment and experimental determination of terminal characteristics of components and simple circuits. Course II continued and expanded on the learning of measurement techniques and equipment useage while applying them for measurements on more complex circuits and systems. Course III was project oriented where the student would choose three of five topic areas for a more detailed experimental study.

There were difficulties related to effective operation of Course III from the beginning. Some of these were: (1) equitable accounting of faculty effort for teaching load considerations, (2) equitable distribution of students among the study areas, (3) maintenance of uniform procedures for determining effort, depth of study and grade assignment among the study areas and (4) maintenance of uniform quality control on lab notebooks and formal reports. Not many remedies were offered but general faculty dissatisfaction seemed to prevail regarding Course III.

Starting with the Winter semester of 1977, Course III was abolished and each student is now required to choose three 4 credit courses from eleven areas. These are courses where laboratory is again more closely linked with specific subject matter and the student must do lab work not just solve homework problems or listen to more lecture. The areas of choice are advanced automation, antennas and wave propagation, artificial intelligence, automatic control, bioengineering, communication and information systems, digital and hybrid computer systems, discrete and integrated electronics, network, power engineering and energy systems, solid state devices. Each course is supervised by a professorial faculty member who has the responsibility of developing and presenting a truly integrated lecture-lab course. There are problems of equipment, space and time to be worked out but renewed faculty enthusiasm and student interest should help ease the "retrenchment" and smooth the transition.

WIND LOAD ON BUILDING--A FLUID MECHANICS EXPERIMENT FOR CIVIL ENGINEERING STUDENTS

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INTRODUCTION: Civil engineering departments in the U.S. and in many other countries traditionally require their undergraduates to take a course in hydraulic or fluid-mechanics laboratory. Seldom in such a course is the subject of wind load on building studied. This constitutes a serious omission because of the large number of civil engineers working in the structures area and because of the importance of wind load to the structural engineer. The Civil Engineering Department of the University of Missouri-Columbia has sought to correct this problem by offering continuing education short courses on wind loads to practicing structural engineers and requiring its won undergraduates to run a wind load experiment as part of the fluid mechanics lab course.

PURPOSES:

1. To learn how wind produces pressure and forces on buildings.
2. To see how wind loads may be determined from model tests.
3. To observe how the external pressure varies around buildings, and how the internal pressure changes with building openings.
4. To observe the drastic effect caused by opening a window or a door during high winds.
5. To gain a basic understanding of building aerodynamics.
6. To learn the basics of wind tunnels and Pitot tubes.

APPARATUS: A wind tunnel with a 1m x 1m cross section, maximum wind speed approximately 30 m/s; building model (block type building of size 13cm x 13cm x 26cm); precision manometer; multi-tube manometer; Prandtl-type Pitot tube.

PROCEDURE:

1. Place the building model and the Pitot tube in proper places in the wind tunnel and connect pressure taps to manometers. The micromanometer is used for the Pitot tube readings.
2. Make sure that the two windows on the model are closed.
3. Turn on the tunnel and increase the speed to 30 m/s.
4. Record the wind speed indicator and Pitot tube readings.
5. Observe and record the liquid levels in the multi-manometer tubes. See if in general the pressure on the windward wall is positive, while the pressures on the roof, the sides, and the leeward wall are negative, as they should be. Is the internal pressure positive, negative, or approximately neutral? See whether the ambient pressure is below or above atmospheric. Do the observed results make sense?
6. Slowly reduce the wind speed to zero, open the windward window on the model, and then slowly increase the wind speed back to the same as that of the previous run.
7. Observe if the liquid level in the manometer tube marked 'interior' has changed from the previous run. Is there any change of pressure in other manometers from the previous readings? Do the results make sense? Record the results.
8. Again reduce the wind speed to zero. Close the windward window of the model, open the leeward window, and have a wind of the same speed as before.
9. Repeat step 7.
10. Reduce the wind speed to zero and turn off the tunnel.

RESULTS:

Based on the data gathered, calculate the dimensionless pressure (pressure coefficient), C_p, at each point. Plot the distribution of C_p (contours) on the roof and the walls (windward, leeward, and side), and get the average C_p for each of these surfaces. Then, determine the net force on each wall and the roof with and without window openings.

AN ELECTIVE LABORATORY COURSE IN HEAT TRANSFER & FLUID FLOW

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The authors have developed over the past several years an elective, upper level laboratory course centered around the performance of the following titled experiments:

Flow Through Orifices
Pipe Flow
Analog Field Plotting
Radial Flow Between Parallel Circular Plates
Forced Convection in a Pipe
External Boundary Layer Flow
Heat Transfer From Fins
Thrust From a Nozzle
Heat Exchangers
Radiation

A student leader is assigned the responsibility for coordinating each experiment. The experiments are preceded by a lecture covering the essential theory behind the experiment, and a detailed instructional sheet is available prior to running each experiment. The students prepare a report for each experiment, with the emphasis being placed on presentation of results (quite often graphical) and on discussion of results.

The majority of the financial support for developing the laboratory equipment necessary for offering the course came from an NSF equipment grant, plus some College and departmental support, as well as some surplus equipment. About one-third of the experiments are modular units purchased from educational equipment manufacturers, and the remainder were designed and constructed by the authors.

The course is very well received by the students, in spite of the aversion commonly associated with laboratory/report type courses.

DOUBLY TUNED AIR CORE TRANSFORMERS

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In the past we had tried plotting voltage gain vs frequency curves run at RF for various couplings using a cut away IF transformer. Parasitic effects destroyed the predicted symmetry and physical breakage of the mica insulation in the tuning capacitors as well as breaking of the fine wires as students tried to tune the circuit and adjust the coupling gave endless trouble.

We now use current gain vs frequency and run the experiment at 20kHz using equal millihenry adjustable inductors as the transformer. Adding R in series with each coil to give Q_o=10 and using an AC bridge to give the desired mutuals has given predictable curves. Setting kQ=.414 gives single peak curve with peak of .707 of the critical curve. kQ=1 gives the flat-topped curve having $\sqrt{2}$ f_o/Q.bandwidth, while kQ=2.414 gives two peaks separate by valley point of .707. This latter curve then represents the maximum coupling which can be used before the circuit produces two pass bands.

FEEDBACK AMPLIFIER PARAMETERS

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In the study of feedback amplifiers, the problem of how to measure unfamiliar parameter using the curve-tracer data was solved by first writing the well known linear expression and then converting to functional notation.

Thus for the series-current feedback connection we want to find g-parameters to check theoretical predictions.

$$i_1 = g_i v_1 + g_r i_2 \qquad \text{or} \quad i_1 = f_1(v_1, i_2)$$

$$v_2 = g_f v_1 + g_o i_2 \qquad v_2 = f_o(v_1, i_2)$$

It is now obvious one should plot i_1 vs v_1 with i_2 as the parameter for the input characteristic curve and plot v_2 vs i_2 with v_1 as the parameter for the output characteristic.

g_i is slope of input curve at the Q-point and g_o is slope of output curve at Q-point. g_r is the ratio of the increments of i_1 to i_2 along a vertical line through Q-point on the input curve, while g_f is evaluated similarly on the output curves.

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Traveling Waves Laboratory

The analogies which exist between different kinds of traveling waves on distributed parameter systems can be effectively demonstrated in the laboratory. The students' appreciation of wave motion is enhanced by observing and measuring wave behavior of several types.

The following experiments are suitable for use in a laboratory on traveling waves. At Nebraska this laboratory is a part of the course which treats transmission lines and plane em waves.

1. Coaxial slotted line (UHF frequency range)

   Measure wavelength, VSWR, load impedance.

2. Slotted waveguide (X-band)

   Measure wavelength, VSWR, load impedance, calculate phase velocity.

3. Microwaves in air (X-band)

   Measure wavelength, calculate velocity, observe Doppler shift and demonstrate velocity radar.

4. Ultrasonic waves in air (40 KHz)

   Measure wavelength, calculate velocity, observe reflection characteristics.

5. Ultrasonic waves in water (50 KHz to 1 MHz)

   Measure wavelength, calculate velocity, observe reflection phenomena.

6. Transverse vibrational waves on taut wire (40-200 Hz)

   Let the wire carry current supplied by oscillator. Place magnet so field is perpendicular to the wire. Observe the standing wave on the wire. Fundamental and several harmonics can be observed. Change wire tension to change resonant frequency.

7. Compression waves in a bar.

   Attach strain gauge to the bar or attach piezoelectric transducer to one end. Strike bar with a hammer and observe compression pulse, observe reflections, calculate velocity of propagation.

8. Thermal diffusion waves in a brass rod (1" dia.)

   Place several thermocouples along a brass rod and wrap rod with insulation. Alternately apply heat (blow torch) and cold (dry ice) (30 seconds each). Observe diffusion type traveling wave and reflection from end.

For additional information, contact Professor Allen R. Edison

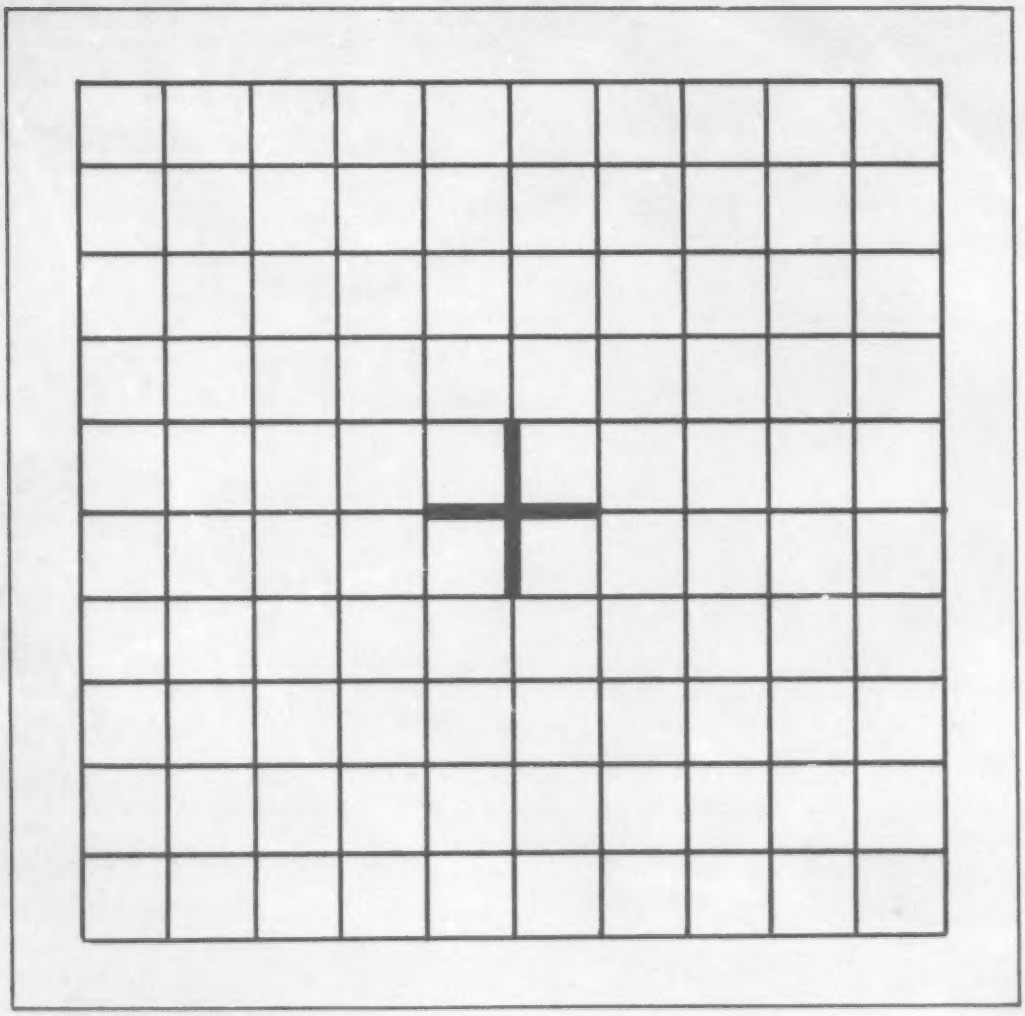
Title of Contribution: A Student-Generated Statistics Problem

Author: Prof. Glenn L. Downey
Author Affiliation: University of Nebraska - Lincoln
Author Address: 216 Bancroft Hall, University of Nebraska - Lincoln, Lincoln, Nebraska 68588

Requests by Engineering students for data that would be useful in statistical analysis led to the author's development of the following procedure whereby the student may produce his own data.

A square grid dart board target is constructed as shown. The student tapes a xeroxed target sheet to a corkboard background and proceeds to throw a prescribed number of darts in a repeated sequence until he has the desired number of points. Loss of points by overlap is easily avoided by numbering the points as the darts are removed. When finished, the student removes the sheet and proceeds with a statistical analysis of the vertical deviation and horizontal deviation.

With a similar circular target, radial deviation could be studied.

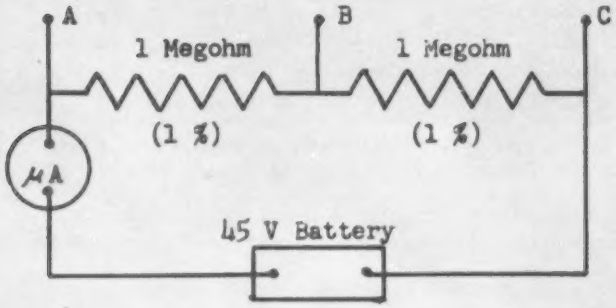


Title of Contribution: Voltage Measurements in a High Resistance Circuit
Author: Prof. Glenn L. Downey
Author Affiliation: University of Nebraska - Lincoln
Author Address: 216 Bancroft Hall, University of Nebraska - Lincoln
Lincoln, Nebraska 68588

The special problem that is encountered in attempting to obtain voltage measurements in a high resistance circuit provides an interesting demonstration in the classroom or in the laboratory of instrumentation classes.

This demonstration also gives the student an insight into the nature of certain impedance-type problems that exist between instruments such as signal amplifiers and X-Y plotters.

The following circuit and the Table of Data show the influence of the particular voltmeter upon the performance of the basic circuit.



Voltage readings, A to B and B to C, are taken sequentially.

TABLE OF DATA

Instrument	Triplett 1000 Ohms/Volt	Triplett 1000 Ohms/Volt	Simpson 20,000 Ohms/Volt	Simpson 20,000 Ohms/Volt	Hickok 209A VTVM Approx. 10 Megohm Int. Resistance
Volt. Range	50 Volts	250 Volts	50 Volts	250 Volts	120 Volts
Batt. Volt.	46.5 Volts	45.0 Volts	46.7 Volts	46.0 Volts	47.0 Volts
A-B Volt.	2.0 Volts	3.4 Volts	15.4 Volts	20.0 Volts	22.5 Volts
μ Amp. Rdg.	45 μAmp.	39.5 μAmp.	31.5 μAmp.	25.5 μAmp.	24.3 μAmp.
B-C Volt.	2.0 Volts	3.4 Volts	15.4 Volts	20.0 Volts	22.5 Volts
μ Amp.Rdg.	45 μAmp.	39.5 μAmp.	31.9 μAmp.	25.5 μAmp.	24.3 μAmp.

As the internal resistance of the voltmeter is increased, the shunting effect across the circuit resistance is decreased. Thus the VTVM yields the most reliable voltage readout with the least interference within the original circuit.

USE OF COMPUTER & COMPUTER-PLOTTER IN MATERIALS TESTING LABORATORY

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Our Materials laboratory course which meets once each week for two hours and one credit hour is a study of the behavior and determination of properties of materials under tensile, compressive, torsional, flexural, impact, and repeated loading. Combined stress by Mohr's Circle of strain analysis, stress concentration, hardness and column action are also covered. One of our Mechanics of Materials courses must precede or parallel this laboratory course which is usually taken in the junior year. In their freshman year the students have had an intensive course of study in the use of FORTRAN IV and related digital PLOTTER languages. In another course they have also had instruction in construction of Engineering Graphs.

The Analysis of several materials laboratory tests require that much data needs to be reduced to a form to be plotted graphically. This requires much tedious, boring, student time. To reduce this time requirement and to provide additional comparative data results for study, ten Computer & Computer-Plotter programs have been developed and written for use in the laboratory course at Nebraska. These programs are to be briefly described in the following paragraphs.

The first two programs developed converted loads and deformations into stress and unit strains which were converted to a plotting language on tape which in turn was carried to our Complot Plotter for the graphical plot in essentially standard form. The results of concrete 6" x 12" cylinders in compression were first plotted. Next the data resulting from standardized wood compression tests of 2" x 2" x 8" wood blocks were manipulated and plotted. Then a program was written to handle data from a standard 0.505" dia x 2" G.L. Tension test of mild steel and converted into a 2 curve stress-strain plot together with suitable title, subtitle information and nameplate data. Since I usually also have tension tests on a Structural Steel Rebar (8" G.L.) and on one of the Aluminum alloys, another program was developed for each of these. This makes five time-saving programs for use early in the semester.

A sixth program to reduce the raw laboratory data into plottable form was written for the Column test which I usually run for my multiple sections. It takes the data for up to 100 wood specimens (50 pinned-end and 50 fixed-end) (width, thickness, length and critical buckling load) and converts the data into a plot of Stress vs Slenderness Ratio for P.E. and F.E. curves. For comparison purposes with the student's experimental results, curves are plotted from Euler's equations for pinned-end and fixed-end conditions, and for three empirical equations for wood columns.

In an effort to make comparative test data more readily available which is intended to give the student more confidence, and meaning to their test results and in the uniformity of standardized test results, four programs were written which tabulate the results from many previous student laboratory tests of concrete cylinders, wood compression blocks, flexure of a standard wood beam and our torsion test. These programs also find the largest and smallest values and averages of such values as: proportional limit stress, yield point, ultimate stress, modulus of elasticity, the energy absorbed, the shear strength (these from flexure) and other values as obtained by particular tests.

One student in each class is asked to punch the data cards for one parameter, such as the loads. This task usually takes him only 10-15 minutes. No great burden. The use of these briefly described ten programs have in general been well received by the students taking the materials testing laboratory course for the past 4 or 5 years. They would rather not go back to the old system of hand plotting even fewer data points and omitting some of the current tests or special test demonstrations.

DETERMINING OPERATIONAL CHARACTERISTICS OF A MEASUREMENT DEVICE WITH MISSING SPECIFICATION

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Students of engineering should be asked to solve industrially relevant problems. Money available for expenditures of laboratory equipment in colleges and universities is often limited. With these two facts in mind, an unconventionally laboratory investigation method was designed. Rather than require a student to perform a laboratory-type experiment, a student was asked to determine capabilities of a measurement device whose specifications were missing.

This method is not limited to measurement devices but it does fit well with them. Characteristics such as range, accuracy, precision, calibration procedures, operating procedures, safety precautions and special instructions are the specifications. Some or all of these specifications may be missing and yet the device still functional. This is a realistic situation and one to which a student can be exposed.

Obtaining a device that is inexpensive that can be used for student projects is relatively simple. Usually colleges and universities have access to a U. S. Government Surplus Center. Functional equipment is often free and usually some of their specifications are missing. The cost involved may only be the transportation to and from the Surplus Center.

Obviously some equipment selected may be useless and/or obsolete for its intended purpose, but requiring a student to uncover that fact is a valuable educational experience. If, for example, circuitry analysis is involved, guidance by qualified individuals may be needed, but again determining the need for such help is a worthwhile encounter. A search for information from vendors, manufacturers and distributors usually ensues, which again is a useful experience.

An example of this method is discussed in the paper. The method is straightforward and inexpensive plus providing a practical experience for students.

FIRST MATERIALS COURSE: LECTURE SUPPORTED LABORATORY

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Many required courses meet substantial "buyer resistance" if a student feels that a specific course is not important to the chosen major field. A Materials course, especially the first one, is often viewed in this light by many students since few are materials majors. Some of these courses have laboratory sessions in which, at least in some situations, the required exercises seem rather humdrum and routine to the student. Faculty, of course, obviously believe these courses are important, since the courses are required.

Use of engineering cases, especially for laboratory exercises, catches the attention of many students. Since cases, such as those available from the Engineering Case Library at ASEE Headquarters, are written about actual situations and circumstances, the student can relate personally to many of these. The instructor can use a series of engineering cases to provide both a framework and motivation for studying theory. Thus the lecture/recitation periods are used to support and illuminate applications. This gives a different format to the course making it rather flexible and unstructured while proceeding in a very natural sequence.

It is relatively easy to broaden the focus beyond theory since a number of factors such as design aspects, litigation potentials, engineering responsibilities, economics, cost, etc., which bear on engineering practice are involved in such situations. The students come to recognize that there may be a number of possible (and acceptable) solutions to a given problem. The instructor has the freedom to formulate questions to focus attention in any desired direction or emphasize any desired aspect.

Law, business, and medical schools have used the case method extensively to educate students. Engineering can profit equally as well. Many engineering faculty have found that use of cases is stimulating and enjoyable for students (and faculty, too).

TITLE: Electronic Laboratory Breadboarding Technique

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Breadboarding of various electrical and electronic circuits for student laboratory work in a simple, fast and convenient manner has always been a problem for the student and usually expensive and time-consuming for the school in terms of fabrication and materials. This proposed breadboarding technique is simple, inexpensive, virtually free of electrical connection faults and can be easily fabricated to suit your own application.

The apparatus consists of a 12-inch by 16-inch x 3/4-inch thick formica covered particle board (sink cutouts from kitchen counters work well). The four sides of the board are beveled at 45° x ½-inch on the bottom side to make a convenient means of picking up the board when it is sitting flat on the bench.

On the board a superstrip is located for mounting transistors, integrated circuits, resistors, capacitors and any other electronic components with leads smaller than #20 guage. For other components with larger leads and interconnecting points, spring clip terminals from General Electric Associates, Inc., Northfield, Ohio are mounted on the board in a convenient pattern with #4 by ½-inch pan head sheet-metal screws.

All circuit connections are made on the board by using standard components and solid insulated #22 wire supplied for the student in one-pound rolls with a small wire stripper attached by a short chain.

Now, let's see why this is a more convenient, less expensive, and more trouble-free breadboarding technique than you are presently using.

1. No preparation and/or mounting of components on special bases is required. Obviously then, replacement components may be purchased locally and any stock components used as necessary for particular experiments.

2. No fabrication of special leads is necessary for circuit interconnections.

3. Bad circuit connections are almost 100% eliminated.

4. Faster hook-up time.

5. Students can write directly on the formica to assist in locating circuit measurement points.

6. Board identification can be directly painted on the bottom. This, plus its size helps prevent loss by theft.

TITLE OF CONTRIBUTION: Analog Multipliers and Other Operational Modules, A New Approach to the Communications Laboratory

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The organization of a satisfactory laboratory series to accompany a Communication Systems type course in a two-year Associate Degree level program is a difficult task, as the time available is short, the student's background is limited, and communications equipment is usually quite complex. This almost invariably leads to a "modular approach" whereby the equipment is broken into functional blocks which can be studied one at a time before the final system is assembled. The real problem has been finding suitable hardware. Not only must the functional blocks correspond closely to the theoretical blocks shown in the textbooks, but they must also be easy to use and understand, relatively trouble-free, and inexpensive enough to be fit into the budget.

The approach we are taking is to illustrate the various principles at relatively low frequencies (less than 100 kHz) using the new generation low cost solid state Operational Modules which have become available. Operational Amplifiers can be used as amplifiers or summing amplifiers and, with the addition of other feedback components, excellent (active) filters. Analog Multipliers are nearly ideal second order non-linear devices, which makes them perfect for use as balanced modulators, mixers, heterodyne frequency translators and square law detectors. The absence of unwanted harmonics makes it possible to obtain excellent agreement between calculated and experimental results--a feature which students find particularly satisfying.

This approach allows the various modulation systems to be assembled on a block diagram basis almost directly from the textbook, and has the added advantage of teaching the students about operational modular components and operational design techniques which they will certainly find useful when they enter industry.

We have found that lab stations consisting of one analog multiplier and two operational amplifiers are sufficient for most experiments. These lab stations can be partially wired (± 15 volt supplies, trims, etc. permanently connected), or the students can easily make all connections using standard industrial breadboarding techniques (Elite breadboards, Superstrips, etc.). A reasonable choice for the Analog Multiplier would be Analog Devices Model 533 (under $15 in a DIP) or equivalent. Any general purpose Op Amp with a Full Frequency Out of 100 kHz or so (Zeltex Zel 1, Analog Devices 118, or equivalent) would be suitable.

DEVELOPMENT OF A BASIC HUMAN FACTORS LABORATORY FOR UNDERGRADUATE INDUSTRIAL ENGINEERING STUDENTS

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New Jersey Institute of Technology
323 High Street, Newark New Jersey 07102

Because of its growing importance in Industrial Engineering, a required course in Human Factors has been incorporated into the undergraduate curriculum at NJIT. The single most important aspect of this course is to teach the basic principles which are unique to experimentation with man. A number of special considerations apply here with which most engineering students have little or no familiarity. For instance, successful measurement techniques require a knowledge of how to: determine minimum acceptable sample size, insure for both subject and group homogeneity, differentiate between intra- and inter-subject comparisons, set up and balance a testing schedule, and compensate for such effects as learning, fatigue and motivation among others. The only realistic way to teach such principles is through active student participation in a number of basic laboratory experiments.

The course is divided into lecture and laboratory sessions of one and two hours per week respectively. In the lectures, students are given an overview of the problems addressed, approaches used, standards adopted, and references available to practicioners in this field. In the laboratory, students are first familiarized with the techniques and instrumentation used by Industrial Engineers in assessing a variety of common Human Factors problems. These include such tools as: light and sound meters, atmospheric monitoring equipment and the like. In addition a number of pieces of special laboratory apparatus are necessary to illustrate many fundamental Human Factors principles. Some of these can be purchased commercially, but many have to be either modified or specially fabricated. Elementary areas for study include: measurement of reaction time (simple and complex), optimization of training schedules, monitoring sensory-motor coordination, principles of physical simulation, and others. It is also quite important for students to appreciate the effects of various common agents on work performance,(for example illumination, noise and vibrations);, the processing of basic sensory stimuli and how the various receptor channels can be overloaded; and how to improve the workplace through redesign, proper tool selection or improved use of controls and displays. Students are instructed to group themselves into squads of three, and are encouraged to select a project which is both relevant to the subject matter and within their ability to complete. A thorough review of the pertinent literature sources is encouraged, and a library of previously submitted reports is maintained in the laboratory for use in addition to other standard reference sources. This approach has encouraged students to follow up on earlier experiments and produce a more meaningful report. The areas chosen have shown considerable imagination ranging all the way from the effects of noise on learning and mental concentration to the effects of alcohol on reflex response and driving ability. We hope to increase the scope and variety of these projects through the purchase and fabrication of new equipment and instrumentation.

TOWARD A PHILOSOPHY OF LABORATORIES

A.J. Perna and D. Hanesian

NCE - NJIT

In defining or delineating a philosophy associated with any laboratory course one must in some fashion, by either tangible or intangible methods, define a set of objectives the program must achieve from an educational development viewpoint. These objectives should be evolved from such inputs as curricula content, career perspectives, economic resources, faculty attributes, etc. The authors hold to the view that a general common philosophy can be developed for laboratories in all fields of studies, however, the methods by which each curriculum reaches these objectives is not the same. A good analogy can be drawn from thermodynamic principles. If one considers the endpoint (objectives) as state functions, (fixed point values) and the method(s) of achieving these objectives, (experiments, areas, form of communication, etc.), as path dependent, then one clearly sees the authors' reasoning.

At NCE-NJIT in the Chemical Engineering Department the following statements, as prepared by the authors, appear in the introductory portion of the laboratory manual for our senior laboratories and is in essence our philosophy.

"The purpose of any chemical engineering laboratory is to serve several important functions in a student's program of development. Among the more obvious are:

(1) To teach students how to communicate results obtained from experimentation through written documentation in a clear and concise fashion.

(2) To put theory into practice in a realistic sense, through a set of instructions, which will require independent logical thinking. The intent here is to compare the theoretical (idealistic) concepts developed in the classroom with the real-world operations (experimental equipment) and realize the limitations of each.

(3) To illustrate the problems associated with leadership and group effort approaches in solving a particular problem. In essence, people working together and contributing to a common goal.

The overall objective is to improve the student's capabilities in these areas and therefore increase his professional competence."

Stating the above is a simple matter but how to achieve the desired goal(s) is another. Therefore the basic problem is, how does one optimize the process to maximize the achieving of the objectives?

Junior Electronics Lab at the University of New Mexico

Charles F. Hawkins and Lonnie L. Miles
EECS Department, University of New Mexico

This paper discusses two innovations regarding the operation of a junior electronics lab at the University of New Mexico. Within the past year this lab has acquired the use of the integrated circuit breadboards called superstrips*. We have also altered the policy of requiring the students to submit formal lab reports each week. Both changes in our lab policy have been favorably received by students and instructors.

The junior laboratory teaches at an electronics level requiring single and double stage discrete transistor circuits, OP AMPS and TTL IC circuits. The use of IC superstrips has virtually eliminated the serious problem of open or intermediate lead connections found in previous breadboard setups. Another advantage has been the practicality of using short one to two inch length wires for the circuit interconnections. The superstrips have become an industrial standard for bread-boarding circuits and are the item of choice for integrated circuit applications. We have found that we can now teach the concept of electronics systems in the lab.

The superstrips have the disadvantage of restricting the wires in the circuitry to be of the order of number 22 gauge diameter. The use of components with wire lead diameters greater than number 22 gauge required the addition of a second breadboard of a different type. A Barry Springboard** was mounted adjacent to the superstrip. The Barry Springboard is cumbersome to use with integrated circuits, but works very well for discrete circuits and for accommodating large diameter leads. Potentiometers are attached either directly into the superstrip sockets using miniature pots or are mounted on clamps next to the superstrip. Both breadboards are mounted on a 3/4" fiberboard. The power and signal leads are connected to banana jacks on the horizontal face of the fiberboard.

A second alteration in traditional lab structure has been the elimination of formal lab reports with each experiment. We felt that good writing practice was not being inculcated. The students generally considered the exercise to be a requirement not a learning experience. The estimated student time required in the formal lab reports was an onorous six to ten hours, and this time was generally spent plagerizing the old reports of previous students.

With these objections we have developed a different procedure. The students now maintain an engineering notebook whose purpose is to record the activities and data taken during the experiment. The students are told in advance the particular circuit to be studied. Their responsibility is to research the circuit from their textbooks and to design a 3 hour lab work activity investigating that circuit. They are encouraged in their planning to explore their own curiosities. Although in some cases a student will not investigate a circuit to the full depth desired we feel that the experience of the student self initiative is more important. Other students perform beyond the levels of a conventionally structured lab.

With this format the students now spend several hours preparing for a lab but almost non upon completion of the lab period. The post lab work usually involves summary remarks of data. The students have expressed favorable opinions regarding the more open lab concept.

*Super-strip™, AP Products Incorporated, Box 697, 72 Corwin Dr. Painesville, Ohio 44077

**Barry Springboard®, Barry Instrument Corp, P.O. Box 252, Los Alamitos, CA 90720

INTRODUCTORY SOIL MECHANICS
DEMONSTRATING EFFECTIVE STRESS PRINCIPLES
QUICKSAND TANK & SLURRY CONSOLIDOMETER

Charles H. Dowding - Associate Professor
Department of Civil Engineering, Northwestern University

Laboratory exercises are valuable supplements to an Introductory Soil Mechanics course to demonstrate the consequences of changes in effective stress, $\bar{\sigma}$, in a soil mass. Effective stress is the stress which affects the matrix of soil solids and is equal to the difference between the total stress, σ, applied to a soil mass less the pore water pressure, u, ($\bar{\sigma} = \sigma - u$). Changes in $\bar{\sigma}$ dramatically alter the soil strength and may cause large volume changes. This effective stress principle is one of the most fundamental concepts in soil mechanics. The effects of changing $\bar{\sigma}$ are visually demonstrated with soil in the two apparatus described with the aid of figures. Both of these apparatus allow a visually exciting demonstration and an opportunity for student-conducted experiments.

The quicksand tank, Fig. 1, was built in 1948 at Northwestern by Dr. Osterberg and is the most popular demonstration at the Engineering Open House. It is made of transparent lucite and is two feet square in plan. This large size allows students an opportunity to "feel" with their hands the changes in sand strength with changes in $\bar{\sigma}$. Water can flow either up, causing loss of strength ($\bar{\sigma} = 0$; the quick condition) or down ($\bar{\sigma}$ increases). Piezometers also provide an excellent visual demonstration of changes in pore water pressure due to water flow and allow the tank to double as a permeameter. Liquefaction (loss of strength during earthquake shaking) can also be demonstrated. Plans and a more detailed description are available upon request.

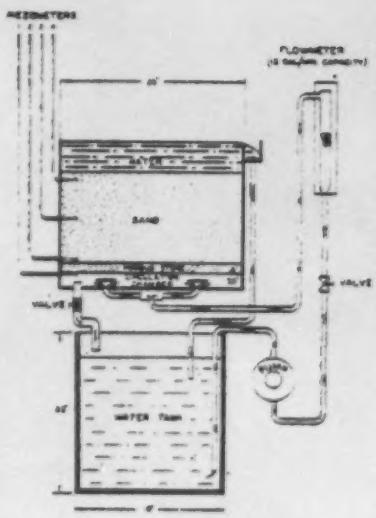


FIGURE 1
QUICKSAND TANK

The lucite slurry consolidometer shown in Fig. 2 is a simple device which shows how the soil volume decreases with increasing effective stress (consolidation). The conventional consolidometer does not permit students to directly observe the volume change and forces them to infer the change from dial gauge readings. The tall lucite consolidometer, on the other hand, permits large changes in soil volume to be seen directly. Effective stress is increased by downward flow of water from the upper cylinder to the bottom cylinder and can be increased by lowering the bottom cylinder. The apparatus allows a direct confirmation of the equality of the volume change and the drained volume of water. The upper cylinder is filled with a special plastic silt, the volume of which decreases rapidly with an increase in $\bar{\sigma}$. Plans for the device and a description of the soil preparation are available upon request.

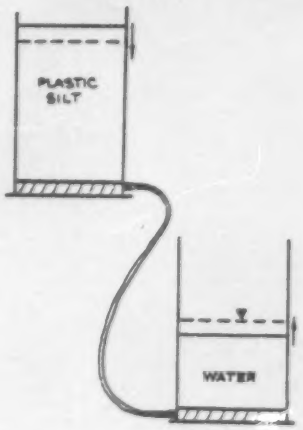


FIGURE 2
SLURRY
CONSOLIDOMETER

Title: CONVECTIVE HEAT TRANSFER MEASUREMENT SYSTEM

Author: G.L. Wedekind

Author Affiliation: School of Engineering, Oakland University

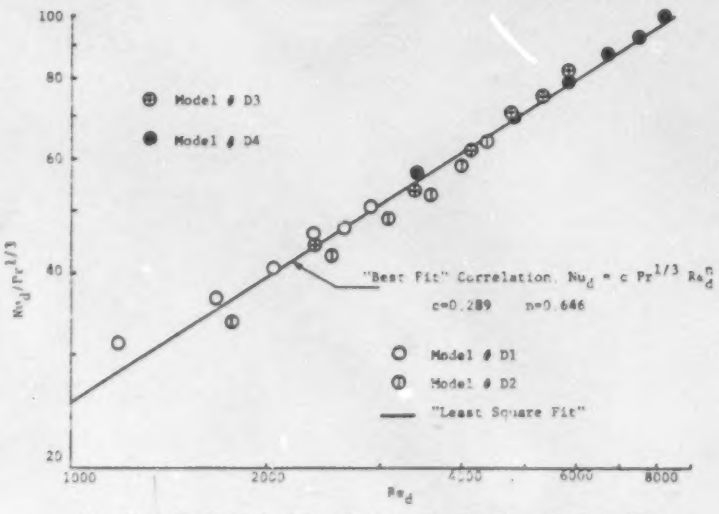
Author Address: Rochester, Michigan 48063

The Convective Heat Transfer Measurement System is an experimental apparatus for measuring the forced and natural convection heat transfer to fluids flowing externally over surfaces of various geometries. From a pedagogical perspective, the apparatus has the capability of providing students with a wide range of laboratory experience with convective heat transfer. This experience includes the experimental development of the classical dimensionless correlations for several geometries, and also the measurement of the heat transfer capability of fins of various geometries and made from a variety of materials. The accuracy of the experimental measurements is exceptional.

The experimental measurement of the convective heat transfer coefficient betweeen a solid surface and a flowing fluid requires the measurement of the rate of heat transfer, the temperature, and the area of the solid surface, as well as the temperature of the fluid. Experimentally, the most difficult of these four measurements to obtain are the first two, especially for geometrically small surfaces or models. In this apparatus, the technique which is used to overcome these measurement difficulties is the use of a thermistor as the geometrical model. When mounted appropriately, and arranged in a particular electrical circuit, both the rate of heat transfer from, and the surface temperature of the thermistor can be indirectly determined.

Using air as the fluid, and by varying the air velocity for forced convection, or the surface temperature for natural convection, it is possible by using various sized models to obtain the empirical correlations for various geometries, both for forced and natural convection. The same technique also makes it possible to accurately measure the heat transfer from a fin. This can be done for various fin geometries and materials, again for both forced and natural convection.

The figure on the right represents an example of the type and quality of the experimental capabilities of the technique. The data is for air flowing past a circular disc, where the axis of the disc is perpendicular to the flow. The maximum deviation of any measurement from the empirical correlation is 14 percent. Similar data can be obtained for circular cylinders in cross flow, where the resulting correlation agrees well with that found in the literature.



Experimentally Determined Correlations. Circular Discs in Cross-Flow

Inexpensive Electro-Optical Motion Measurement Experiment

E. O. Doebelin, Dept. of Mechanical Engineering, Ohio State, Columbus, O.

Cheap infra-red sensors (#S12001, Skanamatic, P.O. Box S, Elbridge, N.Y., 13060, about $30.) can give a useful introduction to non-contacting electro-optic displacement measurement, see Figs. 1, 2, 3. Some possible experiments include:

1. Static calibration. Move target with micrometer, measure e_o with DVM. A DVM with .0001 volt resolution gives an overall threshold sensitivity of about 10^{-8} meters, see Fig. 4.

2. Electrical Noise Problems. Connect scope to e_o in parallel with DVM to observe e_o dynamic behavior. Connecting and disconnecting apparatus bedplate to ground shows large change in e_o "noise". DVM is unaffected since it has a filter. Can now discuss tradeoff of speed / noise if an RC filter were used in front of scope.

3. Motion-Measuring Dynamics. Let sensor view black/white target disk driven at 3600 RPM by hysteresis sync motor (surplus, about $10.), view e_o on scope. Light/dark patterns produce a crude "frequency response" test over range 120 to 1920 Hz. Due to presence of parasitic capacitance C (value not given by manufacturer) in sensor, e_o displays first-order dynamics with time-constant RC. By changing R from 10k to 1k and then 100Ω can observe tradeoff between sensitivity and speed and also estimate numerical value of C.

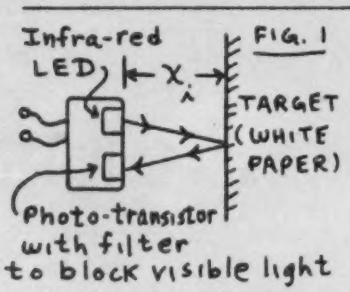


FIG. 1

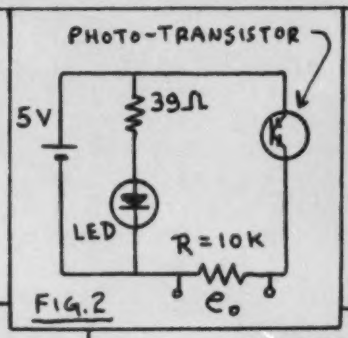


FIG. 2

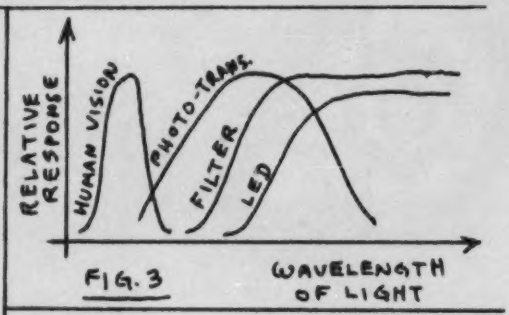


FIG. 3

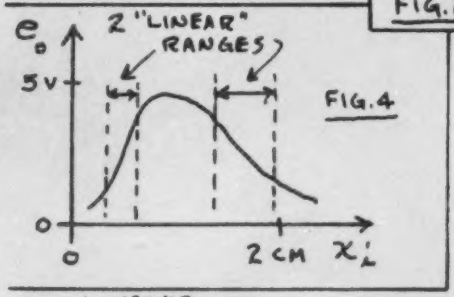
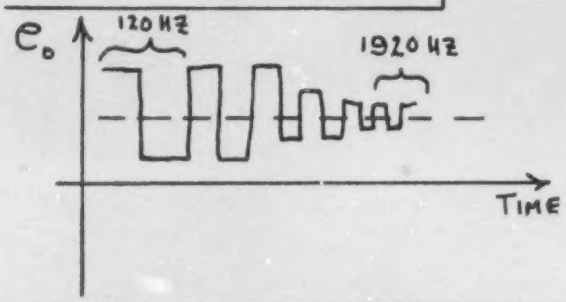


FIG. 4



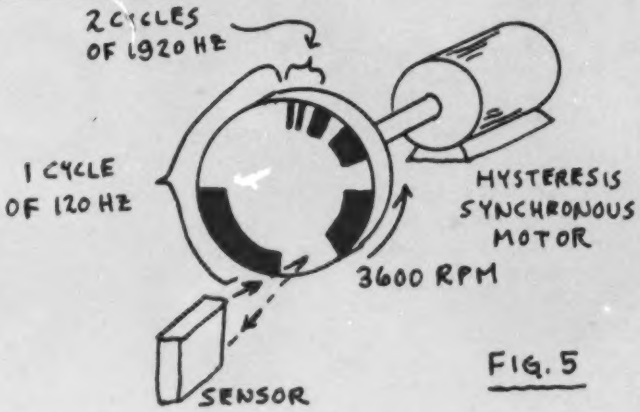


FIG. 5

E.O. Doebelin
Feb 22, 1977

Title of Contribution: Laboratory Educational Aids on the Conference Theme. Food/Resources/Energy/Environment

Author: Edward B. Evans

Author Affiliation: University of Pacific, School of Engineering

Author Address: Stockton, CA 95211

Over a period of five years, I have taught a course, "Man & His Technology, whose content is closely related to this year's conference theme. The following laboratory demonstrations (by students and/or instructor), exhibits, and free movies are used as an integral part of the course.

FOOD
* Demonstration: simple mathematical modeling of exponential growth of population, food, pollution, and energy.
* Exhibits: raw materials, products and by-products in fertilizer manufacture; phosphate rock, fertilizer, shark's teeth, gypsum, uranium, catalysts, sulfuric acid, phosphoric acid.
* Movies: "Food-Or Famine," "Phosphate." "Mission: Technology."

RESOURCES
* Demonstrations: recycling and conservation practices such as recovery of copper from mine waters using tin cans, aluminum from scrap & clay.
* Exhibits: taconite, sea water, low-grades ores as lean sources of vital materials.
* Movies: "Wealth Out of Waste," "There's Plenty of Gold," "Minerals Challenge."

ENERGY
* Demonstrations: operation of alternate energy sources, including solar cell, fuel cell, thermoelectric; measurement of nuclear activity of uranium and mathematical modeling of the decay process; methane from sewage; fuel value of natural gas.
* Exhibits: fossil fuels, including coal, Alaskan oil, oil shale, sludge, walnuts.
* Movies: "When the Circuit Breaks," "The Atomic Search," "Oil."

ENVIRONMENT
* Demonstrations: Cottrell Precipitator, flue gas analysis, noise meter, Geiger counter.
* Exhibits: Phosphate slimes, sulfur, sulfur dioxide, sulfuric acid, ozone, stack gases, particulates, solid wastes, catalysts.
* Movies: "Air Is for Breathing," "River Must Live," "Make Steel-But Keep It Clean," "A Sound Movie About Decibels."

THE FUNDAMENTALS OF PROBLEM - SOLVING LABORATORIES

David R. Voltmer, Assistant Professor of Electrical Engineering
The Pennsylvania State University, University Park, PA 16802

It is in laboratory experiences that the ideal models of the classroom must measure up to the realities of nature. Here at the interface between theory and practice one finds the essence of engineering, "the application of knowledge to the solution of real problems". It is here that the classroom knowledge is put to the test of solving a problem or of designing a system. This is where engineers are made! Recognition and acceptance of these ideas have led to the development of the Problem-Solving Laboratory (PSL) [1], a laboratory experience in which process is emphasized over content. The PSL is not readily explained by examining its salient features.

The Medium is the Message - The process of solving problems is the most important aspect of the PSL. The specific content of the problems is of secondary importance; it serves only as the vehicle through which the problem solving experience is presented. Consequently such a lab can be associated with nearly any course, or it can be independent of any. Since it need not be related to particular material, the PSL is well suited to problems which encompass a diversity of material. Similarly, the level of the course, whether for freshmen or seniors, matters little. The length of the problems can be varied from one hour to one semester according to the limits of the curriculum or the needs of the students. With the emphasis upon the skills of the problem-solving process, student engineers experience a wider variety of problems and are not tied so closely to a particular discipline or technology.

No Unique Answers - Problems without a prescribed method of solution or a unique answer are most preferable in the PSL. The path to an acceptable solution must require numerous decisions by the students--problem definition, assumptions, approximations, relevant theory, measurements, and evaluation of results. Within his decision making process students must sort out the "wheat from the chaff". Problems which require a thorough understanding of the concepts as opposed to merely using several well-known formulas and which are not readily solved by just "tinkering around" are most preferred. In order to avoid biasing the students' approaches to problems, the instructor may select problems which he has not already solved. On the other hand, some preliminary screening as to the difficulty and length of problems will help to reduce student frustration with problems which are beyond their capabilities.

Decision Making and Its Consequences - Students are allowed and encouraged to choose their own methods of solution subject only to their inventiveness and to the time and equipment available. However, this freedom is accompanied by the responsibility for the validity of their approach and the correctness of their results. They are subject to the inflexible grading of Mother Nature; either it works as expected or it doesn't, with no partial credit! Whenever they err, they must determine, interpret, and correct their mistakes.

The Instructor as Students' Model of an Engineer - Students probably have few models of an engineer other than their instructor. How does he approach problems? How does he think? What skills does he use? As an inquisitive facilitator an instructor exhibits to the students his approach to their problem. In addition his probing into their work guides them to further analyze their problems and enables them to discover their own solutions. Formal instruction in creativity and problem-solving skills may be very appropriately included. PSL instruction cannot be left to the inexperienced; it requires qualified practitioners of the art of engineering in the laboratory.

The features merely describe the foundations of the PSL; the particular details are dependent upon the faculty, curriculum, and facilities where it is used. Regardless of the context in which it is employed, the PSL can serve as a vital link between theory and practice--a microcosm of engineering practice.

[1] Young, F. J. and Voltmer, D. R., "The Problem-Solving Laboratory", Proceedings of the Fifth Annual Frontiers in Education Conference , Georgia Institute of Technology, October 20-22, 1975, pp. 62-65.

Title: A Measurements Laboratory for Freshmen
Author: Robert Bonn
Affiliation: School of Engineering, University of Pittsburgh
Address: Pittsburgh, Pennsylvania 15261

An experiment performed by freshmen students in a two-credit course in "Measurements" is straightforward but has features which the student will encounter in later courses in mathematics, physics, strength of materials, etc.

Ten cantilever beams of various cross-sections and materials were built and instrumented as shown in the figure. The lab section is formed into teams and each team is assigned to one of the units.

For the experiment, the teams were asked to do the following:

1) Plot a load-deflection curve and find the spring constant
2) Find Young's Modulus using the beam deflection formula:

$$\Delta = PL^3/3EI$$

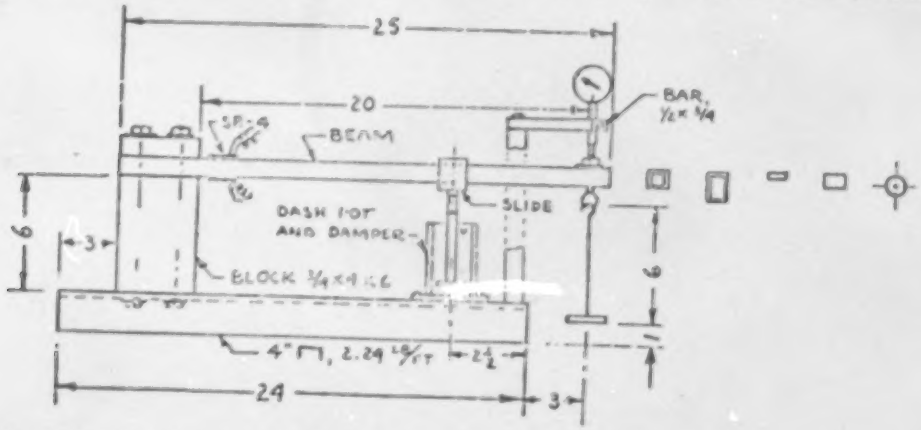
3) Connect the strain gages to a Sanborn Recorder and obtain a record of frequency vs time and find the gravitational constant, g, from the equation:

$$f = \frac{1}{2\pi}\sqrt{\frac{3EIg}{wL^2}}$$

4) Compare free vibration with damped-free vibration

The experiment is described in a manual* which gives the procedure and details the items required for a written report. Thus, the student is introduced to report writing, drawing graphs, and has "hands-on" experience with some sophisticated instrumentation. The lab instructor lectures on bridge circuits, instrumentation, instrument response, and derives the equations and explains them.

The ten cantilever beams are the property of the Freshmen Program. The instrumentation, however, is borrowed from other departments; the dial gages from the soil mechanics lab, the strain gage bridges from the structural lab, and the electronic equipment from various other departments. The experiment takes about two weeks to complete. To date, borrowing of equipment has not been a problem.



*Engineering 2, Measurements Module, Laboratory Manual, University of Pittsburgh Book Center, $2.00. The manual alsodescribes experiments on DC measurements, AC measurements, and has items on report writing, graphical laboratory techniques, and the calculation of experimental error.

Title: Fluid Mechanics Laboratory for Civil Engineering Students
Authors: Robert Bonn, Tin-Kan Hung and Ying Ming Su
Affiliation: Department of Civil Engineering, University of Pittsburgh
Address: Pittsburgh, Pennsylvania 15261

Fluid Mechanics at the University of Pittsburgh is a first junior, one semester four credit-hour course with three credits for lecture and one credit for a three-hour lab. The students enroll with generally little or no background in the subject. Each lab class is limited to twenty students with one teaching assistant.

The first hour of each lab is devoted to orientation for the experiments, oral reports and exchange of information, and the showing of FLUID MECHANICS FILMS.*

At the outset, the students in each lab section are formed into teams of five students per team. Each team is assigned six experiments. The team members take turns being team leader, giving an oral report, and writing a formal report. Each team member is required to keep a notebook with skeletal information which includes data, calculated results, sketches, graphs, etc. The laboratory report and the notebook are graded. A copy of the data sheet for each experiment is given to the instructor at the conclusion of the lab experiment.

Each laboratory commences with a 30 minute film presentation, followed by one of the following lab experiments:

1) Calibration of orifice meter and venturi meter.
2) Determination of the coefficient of contraction for a free orifice from jet trajectory measurements, and calibration of pitot tubes in both water and air jets.
3) Measurements of pressure distribution on a sluice gate and comparisons of the calculated and measured longitudinal forces acting on the gate and the flow rates.
4) Study of water depth variations in super-critical, sub-critical, and critical flows over a hump.
5) Analysis of a hydraulic jump and energy loss.
6) Model study of surge.
7) Resistance coefficients for laminar and turbulent pipe flow.
8) Incipiant cavitation.
9) Pressure valve propogation in water hammer.

Usually only six of the aforementioned experiments are conducted in a semester. Also, the film presentation is coordinated with the lecture insofar as possible which helps to provide background information for each laboratory experiment.

*FLUID MECHANICS FILMS: Nine films are shown each semester from the following:

A. The Hunter Rouse films rented from the University of Iowa, Iowa City, Iowa 52240.
   1) Introduction to the Study of Fluid Motion
   2) Fundamental Principles of Flow
   3) Fluid Motion in a Gravitational Field
   4) Characteristics of Laminar and Turbulent Flow
B. Ascher Shapiro films rented from Encyclopedia Britanica 425 N. Michigan Avenue, Chicago, Illinois 60611
   1) Pressure Field and Fluid Acceleration
   2) The Fluid Dynamics of Drag (four reels)
   3) Vorticity (two reels)
C. Encyclopedia Britanica. A variety of film loops (8-mm).

Title: A Microprocessor Oriented Systems Laboratory

Author: Morton Kanefsy

Affiliation: Department of Electrical Engineering, University of Pittsburgh

Address: Pittsburgh, Pennsylvania 15261

Half of a first term, senior, 4 credit systems lab that requires 6 to 8 hours in the laboratory and 1 hour lecture is microprocessor oriented. The students are expected to have previously taken courses in digital, communications, and control systems, but have little background and no experience with microprocessors.

The microprocessor portion of the lab is divided into two equal length parts. The first part consists of a series of 5 short experiments with the two-fold purpose of constructing a signal processing system while instructing the student how to use the SC/MP microprocessor. There is an emphasis on the microprocessor as a component rather than a computer. The hardware portions of the system, shown in Figure 1,

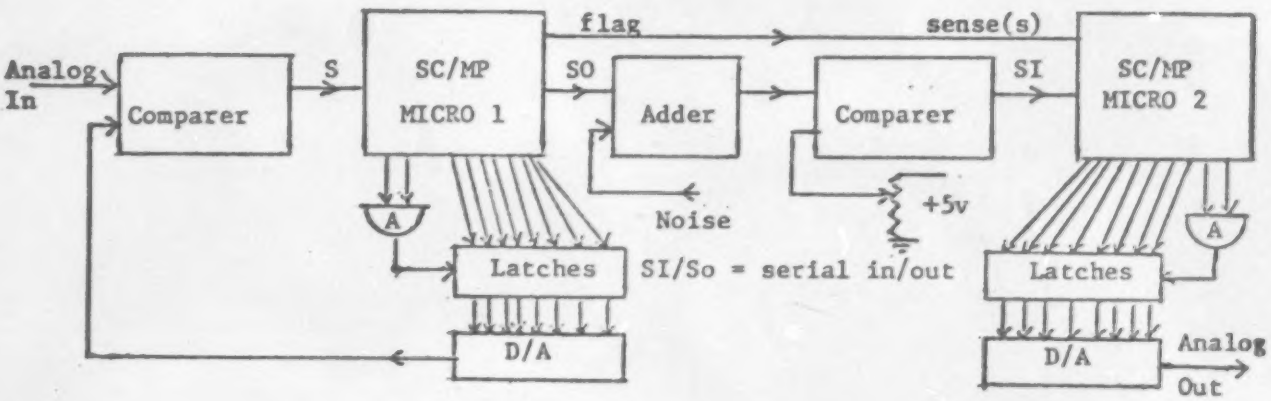


Figure 1 A Signal Processing System

are wired on proto boards by the students prior to the laboratory. Each group of 2 or 3 students must pay a deposit for the components which they keep for the duration of the lab. For the first experiment they are given a program and need learn only how to load the program and read results from a DEC scope terminal. They develop programming skills during the subsequent 4 experiments (the last one being a software analog to digital converter) as well as familiarty with the input/output capability of the microprocessors.

The second part of this lab consists of experiments that utilize the signal processing system. Presently there are experiments in error correcting coding, digital filtering, and digital speed control. The major emphasis of these experiments deal with the effects of signal quantization, sampling rate, and additive noise. An attractive by-product of this lab are the ideas that are naturally suggested for a subsequent senior design project.

Title: Electronics Laboratory at the University of Pittsburgh

Author: Z. H. Meiksin
Affiliation: Department of Electrical Engineering, University of Pittsburgh
Address: Pittsburgh, Pennsylvania 15261

This laboratory course is a first semester junior 3 credit-hour course with 1-1/2 hours lecture and two 2-hour laboratory sessions per week. The objective of the course is to develop in the student the ability to design, test, and characterize electronic circuits. The students attending this course have had a previous course in basic electronic instruments.

The experiment hand-outs give the objectives and specifications of the desired design rather than a step-by-step procedure. The lecture discusses general design procedures appropriate for the experiment to be carried out one or two weeks hence. The student must show to the lab instructor a plan for carrying out the work before he begins his experimental work. All the experimental data must be entered into a log book during the lab, and a report must be handed to the instructor one week after the completion of the experiment.

A list of experiments follows:

1. Diodes, Zener diodes
2. Wave Shaping
3. DTL Logic
4. RCTL Logic
5. Transistor Characteristics
6. Transistor Biasing
7. Audio Amplifier
8. Power Supply
9. Transistor Flip-Flop, Multivibrator, "One-Shot"
10. I.C. Audio Amplifier
11. I.C. Square Wave Generator
12. I.C. Sign Wave Oscillator
13. Active I.C. Low-Pass Filter
14. Active I.C. Band-Pass Filter
15. Electronic System - Event Recorder

Some of the experiments are designed for two-hour lab work, and others for four hours.

TITLE: Environmental Engineering Laboratory

AUTHORS: Ronald D. Neufeld and Yeun C. Wu

AFFILIATION: Department of Civil Engineering

ADDRESS: Pittsburgh, Pennsylvania 15261

The Water Resources and Environmental Engineering Program in the Department of Civil Engineering at the University of Pittsburgh currently offers both undergraduate and graduate-level courses with and without laboratory instruction. In general, the courses in the areas of water chemistry, sanitary biology, unit processes and operations of environmental engineering include laboratory studies and experimentation. The courses are:

(a) Sanitary Engineering Biology (CE 150)

(b) Advanced Engineering Biology (CE 250)

(c) Water and Wastewater Analysis (CE 152)

(d) Unit Operations of Water Treatment (CE 251)

(e) Unit Operations of Waste-Water Treatment (CE 252)

(f) Senior Projects (CE 94)

Computer programming and simulation is used for stream water quality monitoring and for the courses which involve planning.

Task Committees of members of the Association of Environmental Engineering Professors have developed the following laboratory manuals from which lab experiments are selected:

(1) Water Chemistry Manual

(2) Aquatic Microbiology Lab Manual

(3) Fundamentals of Chromatography Manual

(4) Environmental Engineering Unit Operations and Unit Processes Lab Manual

Title: A Laboratory Sequence on the Theory and Practice of Experimentation for Mechanical Engineering Students

Authors: N.H. Wackenhut and R.D. Marangoni
Affiliation: Department of Mechanical Engineering, University of Pittsburgh
Address: Pittsburgh, Pennsylvania 15261

The Department of Mechanical Engineering at the University of Pittsburgh offers a three course laboratory sequence in the last three terms of the undergraduate curriculum. The overall philosophy of the sequence is (1) to introduce the student to the possibilities and to the limitations of the methods of mechanical measurement with emphasis on dynamic and time dependent phenomenon, (2) to apply these principles to mechanical systems requiring several forms of measurement, interpretation, and analysis, and (3) to develop a sense of self-reliance in the student by requiring him, as part of a small group effort, to carry through an experimentally-oriented project from beginning to end. Following is more detailed information for each course.

ME 41, second junior, 3 credits, 2 hours lecture/recitation, 3 hours laboratory. Text: Mechanical Measurements by Beckwith and Buck. Objective: The purpose of this course is to present basic principles and techniques applied to the acquisition of experimental information pertinent to mechanical engineering including steady state measurement but stressing dynamic signal inputs and including detector-transducer elements, signal conditioning and read-out systems. Practical evaluation of instrument and system response and characteristics, instrument calibration, data treatment, error analysis, and standards are studied. Laboratory: Three to four students are assigned to an instrument module equipped with a broad range of electronic equipment. Twelve well structured experiments are presented to the student in a "Mechanical Measurements Laboratory Manual" by Beckwith, Marangoni, and Wackenhut. Some typical experiments performed are: a) Lissajous Diagrams for Measurement of Frequency, b) Short Time Interval Measurement, c) Response of First Order Systems, d) Natural Frequency and Viscous Damping, e) Amplitude, Frequency, and Phase Response of an Amplifier, f) Characteristics of Simple Filters, g) Simple Transducers and Their Characteristics, h) Basic Measurement of Mechanical Strain, and Others.

ME 42, first senior, 2 credits, 1 hour lecture followed by 3 hours laboratory. Text: Same as ME 41. Objective: To develop the student's ability for acquisition, data reduction, interpretation, and error analysis of a complex, preferably time dependent, mechanical system encompassing many forms of measurement and instrument application. Four well structured but intensive three-week duration mechanical systems experiments, each representing one of the basic areas of mechanical engineering, a) thermodynamics, b) fluid/heat transfer, c) stress/dynamics, and d) vibration/acoustics are performed. The thermodynamics area for example is covered by a complete energy balance on a two stage double acting reciprocating air compressor. Two of the experiments must be submitted as total formal written reports. Two of them are abridged.

ME 43, second senior, 3 credits, two 4-hour laboratory sessions. Text: Same as ME 41. Objective: To provide senior mechanical engineering students with a semi-independent experimentally-oriented engineering experience. Small groups of two to four students are required to formulate, design, execute, intrepret and report their findings on a project by formal written report and by presentation at a Senior Technical Symposium. Each member of the Department of Mechanical Engineering Faculty acts as a project director first by providing a suitable project and then by advising the group as needed. Student subject preferences are matched to available projects in so far as possible.

A DEMONSTRATION FACILITY FOR COMPUTER CONTROLLED ASSEMBLY

Michael P. Deisenroth
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Industrial Engineering
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In the early part of the 1975-76 school year, the Whirlpool Corporation donated the remains of a demonstration facility to the School of Industrial Engineering at Purdue University. Until that time the automatic assembly system had been used to demonstrate some of the principles and problems of digital computer control to Whirlpool personnel. The facility consisted of three stations which performed operation in the assembly of a specific component. While only representing a small segment of the total assembly line, these stations did illustrate many of the factors associated with the line as a whole. As received the assembly system had been stripped of an automatic parts feeder and the microcomputer which controlled the stations.

Initially, the efforts of the department were divided into two areas - the basic mechanisms and the control computer. One of the students was assigned the responsibility of assemblying and testing the mechanisms. A manual/automatic control box was constructed to permit individual stations to be switched between manual or computer control. With manual control, the functions of various control lines can be demonstrated to students who will then write the control programs. A second student was assigned the responsibility of providing computer control. A salvaged ASR-33 and a number of "kits" were combined to produce a reasonably powerful microcomputer. Additionally, a TV terminal kit was purchased and assembled to provide for fast, highly visible operator output.

Current efforts are directed at software support. Future students will program the assembly line in a variety of ways. High level language programs will be cross-compiled on the university computer or the departmental minicomputer. Object code tapes can then be loaded for system control. Assembly level language programming will be used by students in the mini/micro computer course. A number of exercises are planned to cover areas as multitasking operations, computer-computer communications, and equipment fault detection. The assembly system will be an intergral part of the course in future semesters.

NUCLEAR ENGINEERING LABORATORY SEQUENCE AT PURDUE UNIVERSITY

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Three laboratory courses are offered every year by the School of Nuclear Engineering for our students: NUCL 205, Nuclear Engineering Undergraduate Laboratory I (sophomore level); NUCL 305, Nuclear Engineering Undergraduate Laboratory II (junior level); and NUCL 504, Nuclear Engineering Experiments (senior and graduate level). All three courses include weekly lectures in which the experiments are discussed and supplementary material is presented. Each course begins with 2 or 3 hours of lecture on the hazards of radiation. Radiation dosimeters and survey instruments are introduced in the first experiment and are used by the students throughout each course.

NUCL 205 is the first college-level laboratory course for most of our undergraduates. Basic experimental techniques are therefore stressed. Experiments introducing the use of the oscilloscope, statistics, and error analysis are performed. GM counters are introduced and are used in experiments involving beta particle and gamma-ray sources. The inverse-square law and the exponential decay of radionuclides are illustrated by experiments. The range of beta particles in matter is measured.

NUCL 305 introduces the use of other types of radiation detectors. Proportional counters are shown to be applicable for alpha particle and neutron counting. Scintillation detectors are used with both single channel analyzers and multichannel analyzers for gamma-ray spectroscopy; neutron activation analysis is performed. Several materials are tested for their effectiveness as neutron and gamma-ray shielding. Flux mapping of a subcritical pile using activation foils is performed to determine the material buckling of the pile.

Students taking NUCL 504 first perform a series of experiments reviewing much of the material covered in NUCL 205 and NUCL 305. The remainder of the course is devoted to experiments using a 1-kW pool reactor. Reactor instrumentation and operation is presented. Experiments involving subcritical multiplication, approach to critical, and control rod calibration are performed.

ROLLING BOTTLES AND VISCOSITY

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The measurement of the viscosity of a liquid is a common experiment in many undergraduate engineering and materials science labs. Sometimes the aim is to investigate the effect of temperature and to measure the activation energy for viscous flow. Or, the effect on viscosity of forming solutions or suspensions may be studied. Unfortunately, most viscosimeters are either expensive, fragile, difficult to manipulate or possess some combination of these drawbacks. A simple device for the measurement of viscosity has been developed that has none of these disadvantages. Yet, it is sufficiently accurate and flexible to permit investigations of a wide variety of viscous phenomena.

The basic principle behind the device is that a bottle, partially filled with a liquid, will roll on a horizontal surface until the viscous drag of the liquid brings it to a halt. The distance required to stop such a bottle is associated with the viscosity of the liquid. The device consists of a low ramp down which a bottle is allowed to roll. At the bottom of the ramp the bottle rolls out onto a horizontal runway that has a distance scale printed on it. When it comes to rest the distance from the base of the ramp to the stopping point is measured and called the roll distance.

It has been found that there is a linear relationship between the logarithm of the viscosity of the liquid in the bottle and the roll distance. Rolling several bottles filled with liquids of known viscosities serves to establish this linear relationship and to calibrate the ramp and runway. Thereafter, the viscosities of other liquids are quickly measured by merely measuring their roll distance.

It is necessary that each bottle contain the same volume of liquid and that each bottle plus liquid have the same mass. Therefore, some bottles must be weighted to offset differences in liquid densities. Small, seamless glass vials have been found to work well as bottles. The ramp must be shallow enough to permit the bottle a smooth transition onto the runway. A ramp angle of about 15° seems to work well. It is also necessary that the liquid slide within the rolling bottle. If it is too viscous or the bottle is rolling too fast the liquid will remain in one part of the bottle and go 'over-the-top' on each revolution. This invalidates the linear calibration relationship and places an effective ceiling of about 10 poise on the maximum viscosity that can be easily measured. This device was originally used with a table as the runway and a meter stick to measure the roll distance. However, a plywood runway with a printed distance scale has been found to speed measurements.

This technique has been used for several years in undergraduate labs to demonstrate all of the viscous phenomena outlined at the beginning of this contribution. It is low in cost and has sufficient sensitivity to yield good, quantitative results. It is easily used by the students with a minimum of supervision and the students seem to enjoy the experiment. It has the additional advantage of demonstrating that experiments need not always involve complex and expensive apparatus and that simple devices can, on occasion, prove to be completely satisfactory. The author fears that in modern labs with automatic, digital-readout devices this latter point is often lost.

Integrating Technical Writing and Laboratory Courses.

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Three years ago within our upper-division Mechanical Engineering Technology curriculum we had a two credit course in Technical Writing and two traditional lecture-laboratory courses (Materials and Mechanics of Materials) all concurrent in the same quarter. The Technical Writing course was operated as a lecture course with various textbook-based writing assignments. The instructor was drawn from the technical faculty. Student progress in the course was slow and both student and faculty morale was low.

The low effectiveness of the Technical Writing course led us to consult with our Learning Development Center to seek advise on improving the course. The approach decided upon was to use the laboratory reports generated in the concurrent laboratory courses as the writing assignments for the Technical Writing courses and to abandon the lecture method for teaching writing. Instead of lectures, an open writing workshop was provided with one technical faculty and one Learning Development Center faculty in attendance. Students were required to bring every report to the workshop for review. Student progress in this course was slightly greater than that of students in a traditional Technical Writing course.

This year we took a further step and consolidated the writing course with the two laboratory components of the concurrent lecture-laboratory courses. This consolidation served to eliminate certain operational problems and more importantly integrated writing performance with performance in the laboratory.

We have been satisfied with student progress using this method. The students have reacted favorably and have been motivated to improve their writing skills. It must be stressed that in such an effort it is necessary to have the full and complete cooperation of the entire departmental faculty. It is necessary for all the faculty to demand quality writing so that students continue to improve their writing and not backslide.

Student Laboratory Proctors - An Effective Way to Reduce Laboratory Costs.

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The philosophy of Engineering Technology programs dictates that these programs include a strong and extensive curriculum of laboratory experiences. Unfortunately laboratories are expensive. The Mechanical Engineering Technology department at RIT received an institutional grant to employ upper-class students as proctors in laboratories. The use of students would eliminate the need for adding additional full-time staff to handle laboratory sections.

The course selected for the trial was "Mechanical Engineering Technology Laboratory" a required laboratory course meeting twice a week which has experiments in mechanics, materials testing, and metallurgy.

Proctors are selected by the faculty based on academic records and ability of the candidates to communicate instructions to other students. They are paid on an hourly basis. The proctors are given a weekly training period on the following weeks' experiments by a member of the faculty. The students in the course are provided with an experiments manual.

The experience has been a good one for all concerned; faculty, proctors, and students. We have been able to reduce the overload on faculty, the proctors have enjoyed the experience, and the students have been very accepting of having upperclassmen as proctors. Further, the administration has been appreciative of the financial savings.

We intend to continue to develop this concept and extend it to other courses.

Strain Gage Technology in Mechanics of Materials Lab.

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A major emphasis in our upper-division Mechanical Engineering Technology program at RIT is on providing a strong hands-on laboratory experience. Since all students enter our program with an AAS degree, they have already been exposed to the basic strength of materials tests (tension test, torsion test, beam deflection test, etc.). In our curriculum, the laboratory activity is built upon this base.

We have decided to provide our students with an exposure to experimental stress analysis using strain gage technology. Students learn the theory and techniques of strain gage instrumentation and apply this knowledge in the laboratory. Six experiments have been designed utilizing strain gages to verify theoretical concepts. The six experiments are:

1. Strain Gage Technology - Mounting Strain Gages.
2. Strain Gage Tension Test.
3. Cantilever Beam Bending.
4. Thin-walled Pressure Vessel.
5. Combined Stress - Superposition Principle.
6. Combined Stress - Rosette Strain Gage.

These experiments are performed using professional switch and balance units and strain indicators. Students are required to read the instruction manuals for all instrumentation and connect the wiring. The structures tested in the experiments were designed and built at RIT.

Electric Power System Protective Relay Test Panel. Student Designed Test Panel for Single Quantity, Differential, and Distance Relays

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As part of a Senior Project in 1973, a student named Steven Sherner, designed a Relay Test Panel for a course in Protective Relaying. Subsequent to his graduation, the panel was modified and constructed. Final constraints were to use standard, 120 Volt, 5 ampere (nominal) relays, and provide the following variables:

Voltage and current were to be adjustable from 10% to 200% of nominal values.

A cycle timer was to be included for measurement of the speed of contact closing or opening.

Flexibility was to be maintained so that change of impedance angle could be achieved.

Metering was to remain external to the panel.

Dual current supplies were to be provided for differential relays, current and voltage for distance relays, and current for over-current relays.

The panel was inexpensive to construct, and has worked well.

AN EXPERIENCE WITH AN INTEGRATED LECTURE AND LABORATORY COURSE

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The Mechanical Design Program of the Department of Mechanical Engineering at Rutgers University includes a dynamics of machinery course for M.E. seniors. This course consists of three hours of lecture and three hours of laboratory each week. The two parts have been integrated into a single course with the same instructor teaching both parts. A graduate student assists him in the laboratory because of the number of groups involved. Normally there have been two sections, each section consisting of twenty to twenty-five students. The instructor has taught courses in mechanical design for a number of years and has developed the course, including the laboratory, and has a strong interest in it. The course is his responsibility. It is, then, within this context that our experience is being cited. Another department having different constraints, including significantly more sections or with a limited number of experienced teachers available, may have had or will have a different experience.

It has been our experience that the course and therefore the design program has been strengthened significantly partly because of this integration. The course is intensive and demanding; it is not considered an easy one. Nevertheless, it has continually received high ratings from the students, including those polled who had already graduated and have been out for sometime.

The course is sixteen weeks long; the sixteenth week, however, is for the final examination. The first four laboratory periods are for instruction in analog computation. The students, of course, have been doing work in digital computation since their freshman year. The remaining periods are for four in-depth experimental investigations; two of these involve prediction or confirmation of the results obtained experimentally, one of the two by the analog computer and the other by the digital computer. Each experiment has been carefully developed to reinforce the concepts discussed in class and to increase the understanding and the proficiency of the students in using related instrumentation.

We have found that the instructor gets to know most of the students far better and more quickly when he also works with them in the laboratory. This understandably means more to the student as an invididual. He knows that he is not just another face in the classroom to the instructor. It should be noted that the presence of a senior instructor in the laboratory emphasizes the importance of the laboratory to the course. The instructor, since he handles both the laboratory and the class continually, finds there is a continuum of unobstructed teaching in going from the class to the laboratory and back. Problems that he encounters arising in the laboratory can be discussed by him in class if desired, and concepts discussed in class can be meaningfully demonstrated and explained by him in the laboratory if needed. This is not to say that this cannot be done if the laboratory and class are not integrated as parts of the same course or if different instructors are involved. For certainly, it can be. It is to say, however, that the flow is likely to be quicker and smoother since only one instructor is involved and feedback is immediate and the full circumstances are known to him.

SIMULATION AND CONFIRMATION IN LABORATORY EXPERIMENTS

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One type of experiment that has been found to be instructive for our students and which has been well received by them has been one in which the response can be predicted by simulation on a computer and confirmed experimentally. The writer has used this method in his vibrations laboratory, which is part of a dynamics of machinery course for mechanical engineering seniors. The method, of course, can be readily used in many other courses and disciplines.

In the writer's course the students simulate the response of an oscillating mechanical system. There are two pieces of laboratory equipment available. For one, the students program their mathematical model on an analog computer to predict the response and to plot it. On the other, a digital computer is used to predict the response and to plot it. Both apparatus have changeable parameters, so different groups of students will have differing data.

By way of illustration, consider the prediction using the analog computer. The students simulate the response of an oscillating mechanical system consisting of a rather heavy mass resting on four leaf springs, the assembly is somewhat like a metal table. The system is designed to oscillate horizontally through small displacements with free motion, with or without viscous damping. Motion can also be forced. The degree of damping and the frequency of forced excitation can be controlled. The actual response of the system can be closely approximated by considering it to be a one-degree-of-freedom system. However, supplemental attachments are on hand to make it a two-degree-of-freedom system. The students are given selected data initially, such as pertinent weights, desired initial conditions for free motion, and a chart of force versus deflection for determining the equivalent spring rate. The seniors then are asked to predict the response of the system on the EAI analog computer in the department. The students previously have had instruction on and some experience with the analog computer. The students are allowed two periods for the simulation.

The actual experiment on the apparatus involves appropriate measurements with strain gages attached to the cantilevered leaf springs to measure frequency and which are calibrated for displacement. The input is fed to a Tektronix storage oscilloscope, and the traces photographed with a Polaroid-Land camera. Measurements are also made using an accelerometer and the signals again stored and photographed for later comparison. Two periods are allowed here for planning the experiment and taking the necessary measurements.

Scheduling, it should be noted, sometimes requires that some students conduct the experiment prior to the simulation; thus, their simulated results are confirmations rather than predictions.

OPEN LABORATORY SYSTEM

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The open laboratory system to be described has been used for several years for all junior and senior level laboratory work in the Electrical Engineering Department at South Dakota School of Mines and Technology. This system keeps the laboratories open for use at times most useful to the students.

There is always a Graduate Teaching Assistant present in the laboratory complex during scheduled hours of operation. The Graduate TA must familiarize himself with all junior level labs prior to the time the students will be performing the lab work, enforce safety regulations, and check off the student's notebook after data has been recorded. He is also available for consultation on any questions that may arise while the student is performing in the lab. The instructors who assign the lab work must make sure the lab and course work are closely correlated, since the student does not receive any direct laboratory instruction. This means that the laboratory work gives direct physical applications of course theory.

A given laboratory exercise may be done at the student's convenience, with the deadline being an assigned due date for the lab report. The open laboratory system gives excellent scheduling flexibility because it eliminates the necessity for scheduling a two- or three-hour block of time for each of the student's courses that includes lab work.

The present schedule is:

Monday and Wednesday:	6:00 p.m. - 10:00 p.m.
Tuesday and Thursday:	9:00 a.m. - 9:00 p.m.

The continuous operation Tuesday and Thursday is in response to student requests. The present schedule has evolved through analysis of data on student usage of the lab facilities.

Under the open laboratory system the student takes responsibility for getting the assigned lab done on time. This responsibility helps develop maturity in our graduates and helps prepare them for their transition from college to industry. Another advantage is that even with limited equipment everyone can work independently. As previously noted, this system also gives excellent flexibility in setting up the student's class schedule. Finally, the open laboratory system makes very good use of the Graduate Teaching Assistants that act as Laboratory Instructors. On the negative side, one problem that has not been overcome is the checkout of small components. A system to solve this problem that involves checkout of a tool and parts kit and assignment of a locker to each student is presently under consideration.

A UNIQUE USE FOR A COMPUTATION LABORATORY

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For years, teachers of problem-oriented structural design courses have sought ways to provide each student with a unique problem, different from the problems of the other students in the class, yet not create for the instructor an impossible task of checking and grading all those unique problems. In the Architectural Engineering Technology Department of Southern Technical Institute, we use a system of problem assignment and checking which provides all of the educational advantages offered by each student working a unique problem; and, while the system does not eliminate the checking and grading time, it does reduce it to a much more realistic quantity.

To facilitate describing this method of instruction, it will be convenient to consider a particular problem. One of the problems assigned in the Reinforced Concrete Structures course concerns the analysis and design of a reinforced concrete rigid frame. The frame is geometrically unsymetrical and it is loaded with gravity type loads placed in a unsymetrical pattern.

Each student in the class is assigned two numbers, an "A" value and a "B" value. The letters "A" and "B" are made part of the dimensions of the rigid frame and appear as part of the load magnitudes. For example, the unsupported span length of the beam might be (25+B) feet or one of the concentrated loads may be (5+A) kips. Since each student in the class has a unique pair of "A" and "B" values, the rigid frame he or she designs is significantly different from any other rigid frame being designed in that class. The variations in this problem that actually exists between each student include much more than the beam span length and one load. Additionally, the "A" and "B" values are involved with the height of one of the two columns and with a second concentrated load. The overall depth of beam cross section is a whole-inch fraction of the span length. This fact not only causes the cross section to vary with "B", but also causes the uniformly distributed load on the beam to vary since it includes the beam weight.

For an instructor to check a problem such as this in a class of twenty-five students would be an extremely difficult and time consuming task. By using a programmable calculator with a typewriter output and a small library of programs stored on cassettes, this task becomes manageable.

The laboratory period associated with this course provides the opportunity for the student, together with the instructor, to check the problem. Several checkpoints are established for the problem and at each checkpoint the student receives the printout providing a correct set of interim answers with which to proceed. The checkpoints for our example problem occur when the student has obtained each of the following: (1) frame analysis by moment distribution to obtain dead-load and live-load moments; (2) beam centerline deflection; (3) column design; (4) footing design. Since the instructor and the student sit at the calculator together, in a "one-on-one" situation, a great deal of individual instruction takes place during these laboratory sessions. The students who are not quite ready for a check use the computation laboratory as a work session with the instructor available to answer questions and give guidance.

This method of using a laboratory period to provide detailed checking of individual student problems has proved very successful since it enables the instructor to keep a close check on the effectiveness of his communication in class and to augment his lectures when necessary.

AN INTEGRATED COURSE OF ASSIGNMENTS, AUDIO VISUAL MATERIAL AND LABORATORY WORK IN MATERIALS TECHNOLOGY

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One major problem in many engineering subjects is to arrange laboratory work so that students have sufficient theory to allow them to understand and therefore gain maximum advantage from the experiments. In this project, the lecture, tutorial, laboratory (LTL) system has been replaced by an integrated system of assignments, audio visual materials and laboratory experiments. The subject used in th project was a two semester, first year subject occupying three hours per week.

In the integrated system the class size was limited to 35, which was later divided into three approximately equal groups. As it is a first year subject, the first week was taken as an introduction and some revision of basic chemistry was carried out. The syllabus had been divided into topics which were arranged so that each group could pursue a different topic.

From the second week, students studied theory in groups of approximately 12, while laboratory experiments were carried out in groups of 4.

Methods of Presentation of Theory

Some topics are best taught by reading and discussion, some by seeing or doing while others just have to be learned by practice. In all topics, students were presented with a set of basic notes, or a reference to the text book page and paragraph if this was felt to be suitable. In some topics students were presented with a series of instructions and questions which, with the notes, provided a programmed text. In this case the answers were handed in, marked and handed back. In other topics, films or video tapes were shown to the group and a brief set of questions had to be answered as before. Yet other topics were treated in the manner of a teaching tutorial group in which the lecturer expounded the topic to the group and then the topic was discussed.

Results

1) There were no statistically significant differences in marks obtained in examinations or laboratory work between students taught by the LTL system and the integrated system.

2) Subjectively, it was considered by staff that :

   2.1 Students of the integrated system performed better in the laboratory. The immediate reinforcement of theory has an advantage.

   2.2 Close association between staff and students because of the small groups was beneficial. In particular this allowed much freer and broader discussion of topics.

3) Students generally said that they preferred this approach, and also commented favourably on the close association with staff.

4) Rigid timetabling of topics and laboratory work is required, however, within some topics, students are able to work at their own pace.

5) The major cost in an educational program is staff. There was very little extra use of academic staff required by the integrated system but more technical support staff time was taken.

Conclusion

An integrated system as described can work. It is believed to be beneficial to students and economically feasible. A fuller description of the initial pilot scheme is available from the author.

Microprocessor Laboratory Projects for EE Project Laboratory

by
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The following projects would be accomplished by a pair of senior students in a 3 week period under the supervision of a faculty advisor.

1. Design and construct a microprocessor unit which will use a thermocouple sensor to measure temperature and correct it for nonlinearities in the curve.

2. Design and construct a microprocessor based digital altimeter which uses an absolute pressure sensor and corrects for the nonlinearities and the altitude above sea level.

3. Build a microprocessor based system to measure the periodicity and amplitude of a periodic wave form (i.e.: square wave, triangular and sine) and output on a digital display.

4. Design and build a microprocessor based system to take the output of a digital tachometer and use it to control the firing of SCR's to control the speed of a motor.

5. Design a TV game of 3-Dimensional Tic Tac Toe. Interface a keyboard TV and the stored program in a PROM.

6. Design and construct an inventory scan and update system using a cassette tape, CRT and microprocessor.

7. Design a speech preprocessor so that sampled analog data can be stored in real time. Play back the stored data.

8. Design and construct a system that stores 500 "Analog" words on a cassette tape. Provide an address code so that the tape can be searched and the analog word can then be played at the proper speed to reproduce the original sound.

9. Given the analog data storage system above, develop a series of sentences by reading from a PROM a sequence of addresses which will extract the "spoken words".

10. Develop a microprocessor based system to calculate Fast Fourier Transforms.

11. Develop a system to automatically record the significant times from an EKG and display the results on a CRT.

AUDIO TAPES IN FLUID MECHANICS LABORATORY

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ABSTRACT

For a period of five years the author has been using audio tapes to guide students performing work in a junior level fluid mechanics laboratory. These students have primarily been enrolled in civil or environmental engineering programs. These labs are typically performed without an instructor present. Despite this, the intention, and the apparent result, has been an increased individualization of the laboratory experience for the students. It was the author's desire to insure close student contact with each experiment, in a "hands on" experience. This is achieved by having students work in groups of three or four. Due to limits on facilities (usually only one or two of a given apparatus), students are in the lab at various times during each week; perhaps as many as nine to ten groups may exist. Having the instructor with each group would result in inordinate time expended, much of it going for mundane explanations of apparatus function.

In order to insure a good student experience and to make student-instructor contact occur over more meaningful matters, the following basic steps are followed. Students receive a written handout on the lab and are allowed to sign up (as groups) for a time to perform the experiment. Experiments are typically set up for one or two weeks, so that the students may perform it any time during that time. The signup procedure assures that schedule conflicts are avoided and alerts the instructor and lab assistant to be available and possibly to drop in on the students. Once in the lab, audio tapes are used to guide students through lab performance.

The student response has been good to this use of tapes. Student reactions have also been useful in modifying tapes. There are, of course, some problems, both administrative (laboratory access, tape access, etc.) and educational (concepts difficult to get across, etc.). Effective tape preparation takes a little practice, but amateurs can do a good job. The author has found it helpful to observe the first few groups using a new tape to detect any material not well explained. In addition, the first lab experience with the tapes should be a good one so the students can more quickly feel at ease. These taped labs can be intermingled with demonstration labs and other large group sessions to provide a good laboratory experience.

EXPERIMENTAL SIMULATION IN FLUID MECHANICS LABORATORY

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EXPER SIM is a term used to represent experimental simulation. As a teaching tool, it was developed very strongly in the psychology area. It has now been employed in the physical sciences area and found of value there. While this author's experience with EXPER SIM is in a fluid mechanics laboratory, other disciplines can use the same basic approach.

The basic philosophy is that the computer is used in an interactive mode as a generator of data for students. The student feeds to the computer values for variables he would ordinarily control in the laboratory and receives in return corresponding values for other variables which he might have measured. These values include "measurement errors." Random errors can be incorporated by use of a random number generator inside the program to perturb results taken from the data bank.

There are a number of reasons for use of EXPER SIM, including a decrease of student time expended in repetitious data gathering, an increase of data available for study, and a lack of equipment. A real caution is noted in that EXPER SIM should not totally replace physical experimentation, but rather complement it. In fact, a proper combination is necessary to establish student faith in the data generated by EXPER SIM.

Typically, the student receives written information describing the problem, along with a set of instructions on the variables, units, and computer prompts (questions) he will see. He then goes to a computer terminal, logs on, and responds to requests the program prints out at his terminal. This generally consists of required input variables, but may include decisions. As each data set is input, the appropriate data (or notation of inconsistency in the input data) is fed back to him. This continues until the student feels he has obtained adequate data.

These programs can be used in one of three modes: 1) as a black box, with no student involvement with the internal program; 2) with small student involvement, e.g. in changing error limits to see the influence; or 3) with the students developing all or part of a data generating program themselves.

Benefits are numerous, but they include especially experience in mapping out research programs, a better feel for the effect of measurement networks and measurement error on results, and provision of more extensive data to enforce a review and explanation of deviations between measurement and theory.

A Student Project Oriented Fluid Mechanics Laboratory

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The Coast Guard Academy offers two junior year courses in the fundamentals of fluid mechanics, one for oceanography and ocean engineering students and another for students in the traditional engineering disciplines. For the past four semesters, the laboratory sessions — two or three hours per week for a semester — associated with these courses have been centered around the presentation and defense of flow demonstration projects conceived and developed by the students themselves. The conduct of these projects is viewed as a step in the student's design education which begins with a freshman introduction to engineering and culminates in one or more senior-level design courses. The projects are often his — or her, since we now have women cadets — first taste of the joys and frustrations of creative design. At the beginning of the semester, the students are scheduled, individually or in pairs, for presentations during a particular laboratory session and are given the freedom to develop a demonstration related to any subject covered up to or near that point in the course. Students have access to a fairly complete collection of the presently commercially available laboratory demonstration equipment, the usual instrumentation, a large wind tunnel, a model towing tank, a circulating water channel, a limited machine shop, and computer facilities.

Some of the more memorable recent projects involved modeling parachute flight in a towing tank, a variety of jet impact experiments, the construction and analysis of the power output of an impulse turbine, comparison of computer developed plots of solutions to potential flow equations (including Kutta-Joukowsky airfoil representations) with Hele-Shaw streak line patterns for the same flows, the development of analogies to flow viewed in a rotating reference frame, an experimental study of hydraulic jumps, field work on the capacity of drainage culverts, and the determination of the lift and drag forces on rotating cylinders as functions of wind speed. The Flettner rotor ship has captured considerable interest with a working model built one semester and a not completely successful attempt to build and race two rotor-powered sailing dinghies the next. As here, the student's enthusiasm occasionally outreaches his time and knowledge resources... usually for the better. Students submit either a written formal report or a display based on their work. Displays have included detailed photographs, computer graphics, and automated slide/voice tape shows.

Apparatus is provided for experiments in fluid properties and statics to those assigned presentations early in the course. Student projects are supplemented by the teacher's demonstrations and example problems and a selection of movies and film loops, mostly from the National Committee for Fluid Mechanics Films library. An outline of a rough chronology of the use of supplemental demonstration devices and films in the course is available from the author on request.

An Undergraduate Ocean Engineering Laboratory Program

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The Coast Guard Academy's ECPD-accredited ocean engineering major, now five years old, is approaching a maturity of sorts. After much ferment, the curriculum has come to contain six ocean-related laboratory courses (in addition to the four navigation and nautical science courses required of all cadets). These are Physical Oceanography and Marine Biology/Geology taught in our science department, "Ocean Fluid Mechanics" described in another paper in the compendium, and courses cryptically named Ocean Engineering Systems Design I, II, and III.

The two oceanography laboratories introduce the prospective ocean engineer to devices, methods, and problems associated with oceanographic data collection and analysis. Both courses include shipboard and field work on the Thames River.

The first course in the engineering sequence, Ocean Engineering Systems Design I (OESD I), develops the basic principles of naval architecture as they apply to a wide variety of floating and submerged structures. The emphasis is deliberately general and not on ships alone. Laboratory sessions are usually conducted in a drawing room atmosphere and involve the layout and analysis of ships and other floating body forms, stability characteristics, and powering requirements. A towing tank and circulating water channel are used in ship resistance experiments.

The second is a computer-oriented course in structural analysis. The laboratory is given over to exercises in the use of finite element analysis, certain "packaged" programs, and design codes. It culminates in a structural design project.

The OESD III course seeks to integrate the knowledge and abilities gained in previous courses and exposes the student to project management techniques, engineering economics, and submarine soil mechanics. (In past semesters, underwater sound was also surveyed. A separate course in acoustics with its own laboratory will be offered next year). The course requires the completion of a major independent design or research project in its laboratory. Some recent projects had to do with the design and analysis of various portions of an ocean wave energy conversion system for buoy powering, the survey of a local spoils dumping area, the feasibility of oyster farming in the New London area, oceanographic survey vessel design studies, the salvage of a sunken sailing ship, comparisons of the holding power of small boat anchors, the effects of pressure on the thermal protection offered by divers wet suits, the forces involved in pulling objects from the bottom sediments, breakwater designs, the effects of shape imperfections on the collapse depth of spherical submarine pressure structures, the preliminary design of an ocean thermal energy conversion plant, comparisons of manganese nodule mining systems, and various computer studies. Many of the projects involved substantial field work and several were done in cooperation with government laboratories and local industries which also supplied speakers for the course. One laboratory session was used to gather river bottom samples and another two to determine their properties in support of the soil mechanics protion of the course. One or two other sessions involve data-taking using the Academy's boats.

Summer cruises and short work-study programs with various Coast Guard organizations involved with ocean engineering complete the student's undergraduate experience.

HEAT TRANSFER - Cooling of a Can of Hot Water

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This "mini" - experiment is performed as one element of a senior level experimental engineering course in the Marine Engineering major at the Coast Guard Academy. One of the weekly labs deals with temperature measurements and associated instrumentation. As one small part of that lab the students are given the following task statement:

> "A can of boiling water will be allowed to cool in air and its temperature will be measured and recorded with respect to time by either a thermometer or thermocouple circuit. Obtain at least a half hours worth of data. We expect the cooling curve to be approximately an exponential decay. Plot Temperature vs time and try to determine the Temperature/time relationship. Consider using semi-log graph paper or various computer least squares curve fit techniques which are available to you. How well does your curve fit the data? Explain why it may not fit well. Discuss important assumptions or possible causes of error. Determine an average free convection heat transfer coefficient - h."

This simple experiment is open-ended and introduces a number of considerations. The classical lumped capacity solution: $T = T_\infty + (T_o - T_\infty)\exp(-hA/\rho cV)t$ can be used to determine h with either a semi-log plot or computer aided least squares fit. Neglecting radiation introduces an error, particularly at the higher temperatures. Conduction through the can bottom to a tabletop is usually a small error. Mixing of the water is frequently neglected. A common trap for students using a curve fit technique, manually or machine aided, is to fit T vs time when it should be T above ambient $(T-T_\infty)$. The error is not obvious to many students until they extrapolate their results to $t = \infty$.

As a "mini" - experiment it nicely complements an analytical Heat Transfer course and points out many of the oversights, assumptions and errors possible with thermal measurements. Of equal importance it is very useful in pointing out the usefulness (and dangers) of curve fitting techniques and numerical analysis of experimental data. It emphasizes the importance of an adequate mathematical model to help gain physical insight.

Development of an Applied Thermodynamics Laboratory Program

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The development of an applied thermodynamic laboratory program provides the opportunity to blend thermodynamic theory with real-life equipment. The use of real-life equipment raises student interest and gives them the opportunity to integrate theory and practice.

In developing the applied thermodynamics laboratory program at Kings Point a methodology has determined which simplifies the task of experiment selection and improves the over-all quality of individual experiments and of the entire laboratory program. A co-ordinated lecture -- laboratory program was developed based on the following three criteria: thermal concepts applied components and engineering conclusions.

An important thermal concept such as available energy was identified as a pertinent topic to be investigated during a particular laboratory period. A suitably instrumented engineering component, a 60 KW steam turbogenerator in this case, was then selected. Lastly, engineering conclusions for specific tests were established, such as the comparison between theoretical and actual performance of a steam turbine under load.

Three procedural criteria to complement the program criteria were also defined in an effort to maximize the effectiveness of the co-ordinated laboratory concept. They were experimental requirements, laboratory resources, and student responsibility. For example, a thermal concept such as available energy was translanted into specific experimental requirements such as finding the loss of available energy due to throttling in a steam turbine. Program components such as a steam turbine are fully explained in procedural resources which include society standards, schematic diagrams of components, equipment operational procedures, and general thermal analysis methods. A proper and efficient laboratory exercise requires responsible student utilization of resources and understanding of systems prior to performing the lab exercise.

Thus, complementing the three program C's" concept, component, and conclusion; are three procedural R's: requirements, resources, and responsibility. The use of these six criteria refines the development of a thermodynamic laboratory program.

FLOW DEMONSTRATION LABORATORY

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In the early sixties, A. Shapiro produced the outstanding educational movie "Fluid Dynamics of Drag." Although it has been (and still will be) used by this writer for some 15 years, experience shows that actual hands-on practice of key experiments tremendously enhances the understanding and retention of the basic concepts. This note describes a permanent laboratory setup to carry out basic experiments relating size, shape, streamlining, roughness, and pressure gradient to drag.

The heart of the system is a 20" x 7' settling tank fitted inside a 12' chemistry lab table. The tank is fitted with baffles, flow guides and screens to direct flow to the 18" x 18" nozzle box mounted on top of the tank. The nozzles - one 5" nozzle and two 4" nozzles are permanently mounted in plywood-fiberglass bases which can be attached to the nozzle box by wing nuts. The nozzles are standard ASME 2:1 spun aluminium nozzles. The flow is provided by a Spencer Co. 1540-H turbocompressor (400 cfm, 40 HP, 1.5 psi p-rise, 3500 rpm const. speed) and the amount (and the nozzle velocity is controlled by an intake gate valve attached to the inlet silencer, and is monitored by pushbutton controls and a calibrated manometer mounted to the tank.

The models are mounted to a lever arm equipped with a vibration damper, and the force is measured by means of a load cell connected to an x-y recorder onto a digital readout. Direct comparative experiments (like smooth and rough spheres for Prandtl-Eiffel paradox) are mounted on a balance arm over the twin nozzles. The models used are: smooth and rough sphere, teardrop shape, 2 round cones with forward and reverse mounting, flat plate normal to the flow (all these have the same maximum diameter); a NACA 0012 airfoil with t_{max} = .5", round rod t_{max} = .5", round wire t_{max} = .03". The airfoil can be reversed to demonstrate pressure gradient effect, and another airfoil is provided with roughened surface. A pitot-tube traverse is also available for axial and radial velocity profile survey of the nozzle flow. An instructor manual is provided.

A FIRST-QUARTER-FRESHMAN ENGINEERING COURSE AND LABORATORY

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A new course, EE 120, Introduction to Digital Systems, has been initiated by the Electrical Engineering Department. This course provides the student with the basic background in number systems and arithmetic, Boolean algebra, combinatorial logic, and sequential logic which he needs to do further work in digital systems. This new course serves the following purposes:

1. Electrical Engineering students are introduced to engineering courses early, so as to increase motivation, maintain their interest, and decrease dropouts. The concepts of digital logic and elementary discrete systems can be grasped by students without the need for calculus.

2. Students are introduced to computer ideas and concepts early so that they can use the computer as a tool in other courses.

3. Digital systems, computer-aided systems, and discrete state systems have pervaded essentially all phases of Electrical Engineering, and an early grasp of digital and discrete systems ideas will improve the proficiency of our students in these areas.

The class has a laboratory associated with it in which the student has the opportunity to design and test logic circuits, simple digital-to-analog and analog-to-digital conversions, simple arithmetic functions, and counters.

A special Digital Logic Trainer (DLT) has been developed by the Electrical Engineering Department and seven prototype units were constructed and are in use. This trainer is a compact console containing power supplies, digital voltmeter, switches, lights, seven-segment readouts, and a digital probe. Digital, analog, and discrete elements are mounted on cards that can be stacked on the console as the design calls for (as many as fifty cards per console), allowing for hundreds of possible design and test combinations.

Nearly 450 freshmen have used this equipment so far. Student reaction to the course and motivation by the laboratory are remarkably favorable.

LABORATORY ORIENTED PROCEDURES

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May 1977

Two committees, staffed by faculty members of the Electrical Engineering Department, are concerned with Electrical Engineering laboratories.

a. The Laboratory Facilities Committee has the responsibility for laboratory space, space organization and utilization, supplies, equipment, laboratory expenditures, student kits, etc.

b. The Laboratory Pedagogy Committee has the responsibility of coordinating and upgrading laboratory teaching procedures and methods among faculty, teaching assistants, and support personnel.

The first obligation of both committees is to insure quality laboratory experiences for learning and instructing. Some procedures that have been effective are listed.

1. A freshman program is offered in the digital area. It is covered in a separate contribution by Dr. O. K. Gehmlich.

2. The laboratories are used by freshmen through seniors. Some laboratory exercises are closely structured while some challenge the student's creativity and ingenuity in designing, assembling, and evaluating to meet given specifications. Six quarter-hours of Senior Projects Laboratory are required for designing, building, testing, and writing on projects of the student's own choice. A Senior Project may involve one or more students. For example, fifteen students worked as a team to design, build, and test an electric car, under the supervision of two faculty members. Every Senior Project has a faculty adviser. Also, faculty members who teach classes with laboratories are responsible for their laboratories.

3. A laboratory manual is maintained for the use of all professors and teaching assistants. All current projects for structured laboratories are kept in the manual with problem solutions. Comments are included to point out strengths and weaknesses, and recommendations are made for future use.

4. All laboratory teaching assistants are screened, instructed, and assisted by the Laboratory Pedagogy Committee, as well as by the professor in charge of each laboratory, to assure quality laboratory instruction.

5. Laboratory aims and procedures are reviewed with the faculty periodically to reacquaint them with the value and present state of the laboratory effort.

JUNIOR LEVEL LAB INSTRUCTION TOWARD SELF-GUIDED EXPERIMENTATION

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Within the Electrical Engineering Department at Valparaiso University, junior level students are required to take a two semester lab sequence. The lab consists of experiments in areas related to their concurrent coursework covering Electronics, Energy Conversion, System Theory, Networks and Field Theory.

The expressed objectives of this lab course which makes it unique are two. First,the student is expected to perform the assigned work in order to glean the technical knowledge from the experiments. Secondly, the student is expected to develop a capability to do experimentation in a self-guided manner.

The first objective is met by careful planning of the expected results and by proper choice of experimental topic. The second objective is met by using a varying style of experiment. The earliest assignments follow a style established in a prerequisite sophomore lab course. These assignment papers introduce the problem, state the objective and give the desired procedure for performing the experiment.

As the year progresses the style is changed gradually. First,part of the procedure information is withheld and students are asked to fill in the gaps. Finally, the entire procedure information is withheld. At that point the student is asked to formulate the entire procedure. To make this feasible, reference material and tutorial help are readily available. At first references are listed, but later they must be sought out by the students.

By the last half of the second semester the assignments are further abbreviated. At this stage only the "problem" is stated for the student. With these assignments the student must find reference material, usually course books, to explain the problem. Procedures must then be designed and results defined. The final outcome is a self-guided experimental situation.

The lab instruction technique described has been found to obtain its stated objectives. The self-guided achievement is witnessed in the senior year when each student performs a required independent study project. The technical knowledge is witnessed in the related course work. While this system of instruction has achieved its purpose it has two major drawbacks. The students feel a frustration due to the changing nature of their required performance. Secondly, the faculty members at times, find it difficult to force the student to use the reference literature available. It is simpler to answer the question than to pinpoint the reference.

In spite of the drawbacks, the system will continue to be used because the self-guided experimentation capability is an expected attribute for any productive engineer.

STEADY STATE HEAT TRANSFER IN TWO DIMENSIONAL OBJECTS

by

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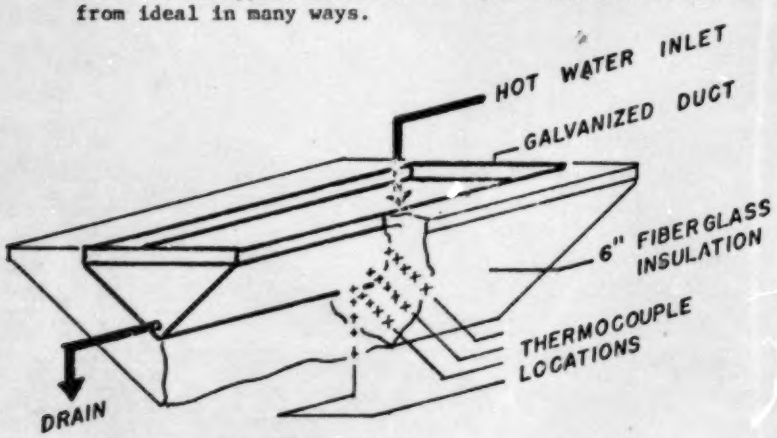
Several steady state heat transfer experiments are currently available to engineering educators. One of which is an electrical analogy using conducting (or Teledeltos) paper. Such devices are academically accurate; however, they do not yield engineering experience that most students will utilize upon graduation. The purpose of this Note is to present how a full scale model of a heated duct with insulation is used to complement such an electrical analogy. The idea was conceived and developed by two senior engineering students. The idea of encouraging capable fourth year students to develop laboratory equipment for both their technical development and for the obtention of equipment is being implemented into the teaching philosophy in the Department of Mechanical Engineering, University of Virginia.

The experimental apparatus consists of one half of a 1.0 ft^2 square duct 3 feet long tilted to one side (see below), which has been insulated with 6" of fiberglass insulation. Constant temperature hot water is circulated throughout the half duct such that the inside wall is at constant temperature. Twenty small thermocouples are imbedded in the insulation at known distances from the inside boundary. Comparison of the temperature distribution in the insulation is compared to results using a finite difference method. Although not required experimental results can also be compared to the conducting sheet analogy results in which temperature distributions can be found. The students are also given the proposition "if 25% more insulation is available where will you place it to reduce the heat transfer". The thermal resistance is measured using the electrical resistance analogy. Wise students utilize a temperature distribution diagram to identify regions of high heat flux. The "plug and chug" students guess as to where it can be added, test the resistance, and reguess, and so forth.

Thus, the objectives of the experiment are to (1) introduce the concept of the electrical analogy of steady state two dimensional heat transfer, (2) make evident the value of this analogy on design considerations, (3) reemphasize the use of finite difference methods, and (4) allow the students to develop experience in taking measurements on an apparatus which is representative of that used in industry and which is far from ideal in many ways.



LABORATORY MODEL

ELECTRICAL ANALOGY

*Assistant Professor, Member ASEE
**Presently Graduate Students

A LASER ACTUATED AUTOMATIC CONTROL SYSTEM

by

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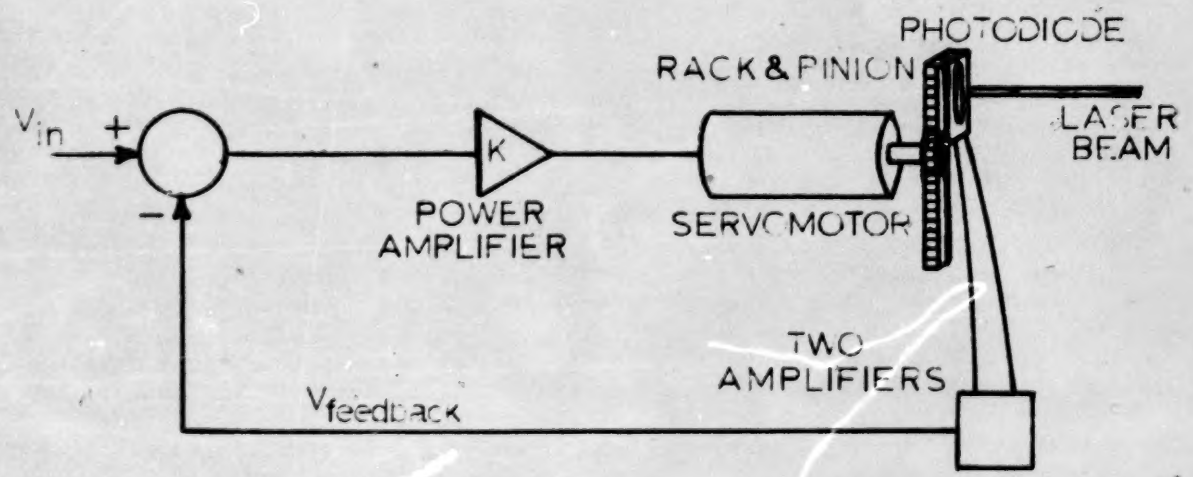
Automatic control systems are often taught using electrical analogies. Mechanical engineering students, however, often desire "hands-on" experience with mechanical equipment. The objective of this Note is to describe an automatic control system which uses a laser and photodiode for feedback control. The experiment provides the basics of a displacement controlled system and also introduces the students to optical sensors. The experiment is in fact a model of a laser actuated control system used on construction sites for leveling of ground. The experiment was designed, built, and tested by a senior engineering student.

The basic system is shown below. It consists of a servomotor, rack and pinion positioner, linear displacement measuring photodiode, two amplifiers to amplify the output from the photodiode, a summing amplifier and a power amplifier. A step input is applied to the power amplifier and the type of response can be changed by varying the gain (K) on the power amp. For low gains (i.e. 0.1) the system is first order dominant. For high gains (i.e. 10) the system is second order dominant. The experiment lends itself well to many variations. Students can vary K and measure ζ and ω_n (or τ's) experimentally. They can derive the overall transfer function for the system and show that it is primarily second order (or two first orders). It can also be used with derivative compensation to improve its stability using an approximate differentiator. Finally, the students are allowed the opportunity to participate in utilizing optical and laser techniques, which are becoming more widespread in industrial applications.

Thus, the objectives of the development of the experiment were two fold. First, to develop a piece of hardware with the above described technical objectives. Second, to allow a senior engineering student to design a piece of engineering equipment for use in future laboratories including all considerations (cost, durability, teaching effectiveness, etc). Several such student projects are completed every year with considerable success.



*Assistant Professor, Member ASEE
**Presently Graduate Student

Title: Production of Hydrogen from Catalytic Decomposition of Methanol

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Objectives:

A two-semester sequence of chemical engineering laboratory is concluded by having the students operate a small, pilot-scale integrated chemical plant. Among the objectives of this experiment are:

(i) To experience operation of a continuous catalytic chemical reaction together with separation and purification of the reaction products;

(ii) To make material balances on the process to determine if the plant is operating properly;

(iii) To consider the kinetics of the chemical reaction, and

(iv) To determine which part of the plant behaves as a "bottleneck" and fails to operate as completely or efficiently as it should.

Description of the Process:

A vaporized methanol-water mixture is decomposed catalytically at approximately 300°C and atmospheric pressure to hydrogen and carbon dioxide. This reaction is endothermic thus requiring input of heat to maintain the desired reactor temperature. The carbon dioxide is absorbed in a packed column by monoethanolamine solution and the hydrogen is metered and vented. The absorber solution is stripped of carbon dioxide which is also metered. Stripped monoethanolamine is recycled to the absorber.

This pilot system includes a number of operations commonly found in full-scale chemical plants. Included here are flow and metering of liquids and gases, vaporization and condensation, distillation, absorption, and catalytic reaction, among others. Each of these could be performed over a range of conditions. Students run this plant in shifts for most of a normal day. After taking rate data and performing some spot analyses, the students make material balances to determine the efficiency of the overall operation and losses that may occur. Further analyses will suggest other operating conditions for subsequent runs so that kinetic reaction rate constants can be calculated from the data.

A Laboratory Course at the Graduate Level in Biomedical Instrumentation

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Biomedical Engineering poses unusual problems in education since the background of entering graduate students is extremely heterogenous. Degree candidates are expected to be competent in physiology, biophysics, and engineering when they complete graduate coursework. Biomedical instrumentation is one of the core courses in the graduate curriculum at the University of Virginia. Only a third of the students have undergraduate degrees in electrical engineering although all have taken some courses in basic electrical concepts. Few have constructed an electronic circuit and none have taken a previous course in instrumentation. With this as a starting point the object of our course in biomedical instrumentation is to provide graduate students with the knowledge and experience to view critically the methods of measuring a given variable, choose a suitable approach given the constraints present, and, if necessary, construct a sensor and the associated conditioning electronics.

The course has historically consisted of three lectures a week for two semesters. This spring the design and implementation of a special project was required, with students working in groups of one to three over a period of one month. A number of projects were suggested by the instructor and the students were encouraged to name as many more as possible. The students then chose the project in which they had the greatest interest. Considerable care was exercised to restrict topics to those relatively sure of success. The projects completed this spring were: ear oximeter, respirator pressure limit alarm, foot plate pressure transducer, nerve stimulator, photic flash peak intensity meter, alpha wave detector, hand-held optical distance sensor and temperature to frequency converter. The success rate was seven out of eight with good efforts on all projects. The student response was very enthusiastic. The use of individually chosen projects is considered to be very important for proper motivation.

In the future, the course is being enlarged to encompass a structured laboratory which will require an estimated eight hours on alternate weeks. A broad selection of basic measurement problems will be assigned and each student will construct his own transducer and electronics. The laboratories include three refreshers on electronics, electronic thermometer, heat flow, metal strain gage, liquid filled strain gage, pressure sensor, linear variable differential transformer (LVDT), non-coherent optics, hot wire anemometer, electromagnetic flowmeter, impedance measurements, biopotentials (EKG), microelectrodes and biopotentials II (voltage clamp experiment). We feel that the addition of supervised laboratory work is of great value, a feeling shared by our students.

DISPLACEMENT METER

W. B. Diboll, Dept. of Mech. Engr., Washington University, Box 1185, St. Louis, Mo. 63130

Washington University in St. Louis requires that mechanical engineering students take a course in measurements during the first, second, or third year. One of the more successful projects is the manufacture and calibration of a displacement meter constructed of a flexible beam to which an electric resistance strain gage has been attached (Fig. 1). The large size version of this type of meter has been used in the railroad industry to measure relative displacements on the order of six inches between carbody and trucks. In the measurements laboratory a small size version is constructed.

The student is supplied with the piece of steel, a strain gauge, cementing equipment, instructions for mounting and soldering, 3 precision resistors, wire, a terminal strip on which to construct a wheatstone bridge, and a potentiometer to balance the bridge.

After attaching the gauge and completing the bridge, it is clamped to a holding device for calibration. Calibration is performed using a micrometer to deflect the gauge, a digital voltmeter, and a bridge excitation voltage supply.

The experimental calibration constant is compared with the theoretical calibration constant. Since many students have not had beam deflection and strain theory, the derivation is supplied, requiring only "filling in the blanks". Nevertheless, this comparison is a necessary part of a designers knowledge and it has proven worthwhile.

This project has been well accepted by the students and has achieved the educational accomplishments listed below. Note that there have been educational achievements which were not part of the original goal.

PLANNED EDUCATIONAL GOALS:

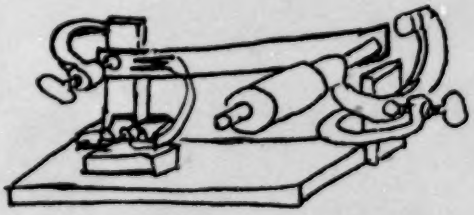
1. Construction of a complete measuring system.
2. Calibration, with estimate of error.
3. Construction and use of a wheatstone bridge.
4. Application of strain gauges.
5. Value of technicians

UNEXPECTED EDUCATIONAL ACHIEVEMENTS:

1. Use of circuit tester.
2. Checking of series parallel resistance in a system which had to be measured.
3. Observing the bending shape of a cantilever beam.
4. That location of the strain gauge affects calibration.
5. That theoretical results are realistic, even if not precisely the same as experimental results.
6. That the input voltage to the bridge is important and must be part of the calibration.

FIGURE 1

Displacement Meter



Title: INSTRUCTIONAL STRATEGY for a DISCRETE COMPONENT ELECTRONICS COURSE
Author: Norman Mahler, Associate Professor
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The trend today in most electronics laboratory courses is toward more and more use of integrated circuits, both linear and digital. While this trend is certainly justified, the need for an electronics technician to be familiar with discrete component linear circuits cannot be neglected.

To fulfill this need the author has developed a sequence of three hour laboratory sessions, concerned with BJT amplifiers, designed to be used within an eleven week linear electronics course to acquaint the student with the pertinent operating characteristics and measurement techniques.

The following material will give a brief overview of each session.

Session I: BJT BIAS CIRCUIT ANALYSIS
A problem solving session designed to acquaint the student with the various bias circuit forms and the methods of analysis.

Session II: BJT BIAS CIRCUIT DESIGN
The student must design, breadboard, and test four bias circuit arrangements.

Session III: BJT BIAS CIRCUIT STABILITY
A more detailed study of the stability concept. Can be included in Session II if fewer circuits are used.

Session IV: INTRODUCTION TO BJT AMPLIFIERS
The student designs the bias network to meet specified conditions, then applies a signal. Load line concept is stressed.

Session V: AMPLIFIER MEASUREMENTS and MODELS
The emphasis here is on the techniques for measuring input resistance, output resistance, and voltage gain for a small signal amplifier. A model is then constructed from the measurements.

Session VI & VII: AMPLIFIER CHARACTERISTICS
Using the measurement techniques from the previous session, comparative data is gathered for four amplifier configurations. Namely: CE, CB, CC, and CE with an unbypassed emitter resistor.

Session VIII: FREQUENCY RESPONSE MEASUREMENTS
Factors affecting the frequency response of an RC coupled amplifier are studied along with the measuring techniques.

Session IX: SINGLE STAGE FEEDBACK AMPLIFIERS
An investigation into the effects of both SERIES and SHUNT feedback.

Session X: AMPLIFIER DESIGN
The student must design, breadboard, and test a single stage amplifier.

Title: CALIBRATING GENERATORS AND MOTORS FOR POWER MEASUREMENT
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The emphasis in the Electric Machinery course at WSTC is to have the students first understand the fundamentals of the various basic machine types and then to understand how to apply them efficiently. The usual older laboratory equipment is a coupled pair of multicircuit ac and dc machines with no provision for one being used as a dynamometer. By carefully calibrating the dc machine, it can be used to measure shaft power whether it is in use as a prime mover driving the ac machine or in use as a generator to absorb power from the ac machine. The process involves careful determination of the dc machine losses over a sufficiently wide operational range:

1)Rotational loss, which includes: bearing friction, brush drag, and windage as well as eddy current and hysteresis losses in the magnetic circuit. The losses vary with rotational speed and field flux. The rotational losses can be determined in the manner described in the accompanying "ROTATIONAL LOSS DETERMINATION IN DC MACHINES".

2) The armature circuit I^2R losses which include the actual copper resistance of the windings and the constant (or nearly so) voltage drop loss of the brush to commutator contact. The armature circuit resistance is not easy to determine but at the same time is most important since the armature circuit losses are the largest single loss in the machine when under load. The armature circuit resistance may be determined by the accompanying "FORGUE'S METHOD FOR DETERMINING DC ARMATURE CIRCUIT RESISTANCE".

3) The various field circuit I^2R losses which may be determined by normal voltmeter-ammeter methods for the coil resistance and by measuring actual current while under test.

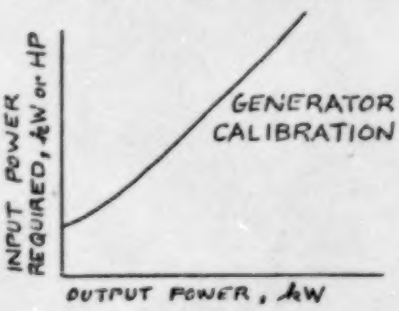
Once the various losses are tabulated or plotted as families of curves as the case may be the input-output relation of the machine can be found from normal efficiency relations where:

$$\eta \text{ (eta) } \% \text{ eff} = \frac{\text{output (100)}}{\text{input}}$$

$$\text{or: } \eta = \frac{(\text{input} - \Sigma \text{ losses})\ 100}{\text{input}} \quad \text{or: } \eta = \frac{\text{output (100)}}{\text{output} + \Sigma \text{ losses}}$$

It is easy to measure the <u>input</u> of a motor and the <u>output</u> of a generator. The process checks well when a dynamometer is available.

From the above equations it may be seen that:
output = input - Σ losses
and: input = output + Σ losses
We may then form accurate input-output relations as shown for a particular speed and voltage.



Title: FORGUE'S METHOD FOR DETERMINING DC ARMATURE RESISTANCE
Author: Donald V. Richardson, Electrical Eng. Technology Dept.
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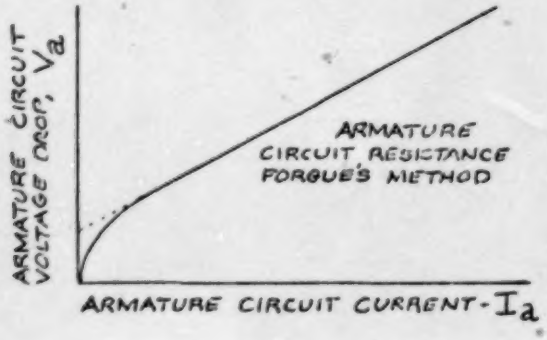
When determining the losses in a dc machine, in order to calculate the machine efficiency or to use the machine as a calibrated motor or calibrated generator, the armature circuit resistance is the most critical parameter. This is because the armature circuit power loss is the largest single loss in the machine. At the same time the armature circuit resistance is the most difficult measurement. When the armature circuit resistance is taken by normal voltmeter-ammeter methods the copper resistance is correct but the brush contact resistance on the stationary commutator is too low. Normally, the armature cannot be rotated at any appreciable speed or the residual magnetic field will cause voltage generation that will produce prohibitive error. When readings for both directions of rotation are averaged the rotation error is cancelled but the moving contact resistance is still understated. The inaccurate readings are conventionally multiplied by "1.2 to 1.6 depending upon experience", which has always been unsatisfactory.

At WSTC, following the work of John Forgue of the class of 1970, we have developed a new method which gives accuracies within one percent as determined by dynamometer tests for machine efficiency. Forgue's method involves the following:

1. Rotate the machine at its normal speed by outside means such as a coupled motor.
2. Buck out <u>all</u> effective residual magnetic field so that no generated voltage can be measured. This will require a small controllable dc source to produce sufficient ampere turns in the field coils so as to just cancel the residual field.
3. Pass an outside supplied current from brush to brush and measure the voltage drop while rotating with the cancelled field. The field will require readjustment at each current level to allow for the armature reaction effect of redistributing the residual field.

The measurements of the armature circuit resistance are best made as a voltage vs current plot to test data reliability. Good data produces a straight line that will project to an ordinate intercept which is the normal brush voltage drop when operating.



Title: MODIFIED KAPP BACK-TO-BACK TEST FOR ACCURATE DC MACHINE POWER MEASUREMENT

Author: Donald V. Richardson, Electrical Eng. Technology Dept.
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In the experimental development of electric vehicle motors two major problems arise. First, the usual laboratory power supply will not supply sufficient current for a cruise power of 20 hp (15 kW). Second, the usual laboratory dynamometer will not absorb more than about 3 to 5 hp (2.3 to 3.5 kW). To test a full scale electric vehicle motor up to the desired acceleration range of power of say 80 hp (60 kW) would then seem out of the question.

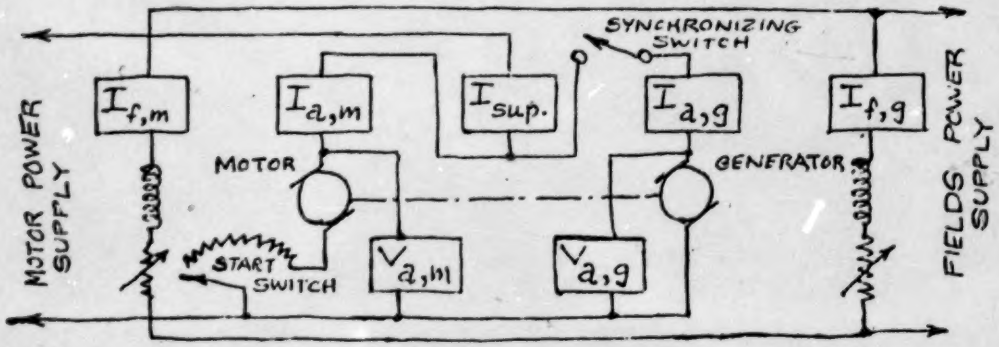
A reconsideration of the old Kapp back-to-back test seems the answer to this dilemma. This test has been extensively studied at WSTC both for vehicle motor tests and for the verification of motor power loss tests as separately discussed under "CALIBRATING GENERATORS AND MOTORS FOR POWER MEASUREMENT", "ROTATIONAL LOSS POWER MEASUREMENT IN DC MACHINES", and "FORGUE'S METHOD FOR DETERMINING DC ARMATURE CIRCUIT RESISTANCE".

The Kapp back-to-back test involves connecting two similar dc machine shafts through belting, gearing, or preferably, shaft to shaft by a coupling. One machine serves as the motor and the other serves as a generator. The units should be of similar power capability, the same rated voltage, and the same speed range. The test is as follows:

1) After starting the motor through a starting switch, the generator voltage is matched to the motor power supply voltage and the units are paralleled through suitable switching. The generator is then floating on the line and the motor is drawing sufficient armature power to supply the rotational losses of both machines. Suitable ammeters measure motor armature and generator armature current. The fields may be advantageously separately excited to secure sufficient range of operation, if required.

2) The generator field excitation is increased which loads the generator, thus in turn loading the motor. Any level of power and speed desired may be reached and held. The shaft power of the motor and generator units may be determined by input - Σ losses and output + Σ losses. The power supplied to the coupled pair is the sum of the rotational losses, and armature circuit losses of both machines. The bulk of the motor power circulates from the generator to the motor.

Our tests have shown the sum of the aforementioned losses to be confirmed by the input power to well under one percent of error.



Title: ROTATIONAL LOSS DETERMINATION IN DC MACHINES
Author: Donald V. Richardson, Electrical Eng. Technology Dept.
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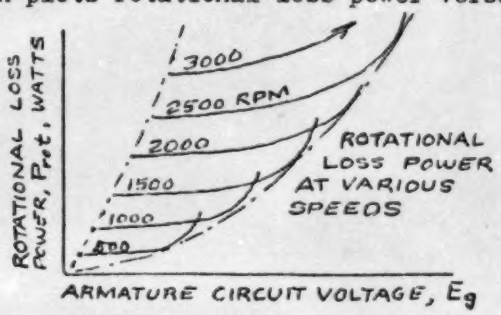
In a continuing study of the requirements of a variable speed dc motor for an experimental electric vehicle it has been necessary to work with dynamically similar models. The realistic transfer of data from model to full scale motor design has required a knowledge of motor losses under a wide range of speed and power. In order to use reasonable values in efficiency calculations, or in the development of a family of calibration curves, groups of students at WSTC have determined that dc machine rotational losses vary widely with both speed and field magnetic flux. The usual single value for rotational loss power is completely inadequate. However, the rotational loss is measured as all the power fed into a dc machine armature when it is running light or unloaded. At WSTC we have developed the following rotational loss measurement procedure:

1) Separately excite the machine field from a controlled and measured source which is capable of supplying excitation current from zero to full normal field saturation. This source should be instrumented for field circuit current. Field connection should be recorded whether series or parallel as far as pole groupings.

2) The armature power supply should be variable over a wide range of voltage from as low as the motor will operate to as high as the machine might be expected to generate in a regenerative braking mode of operation. Armature circuit current and armature brush to brush voltage should be recorded.

3) Data runs are taken at fixed speed increments such as 500 rpm, or comparable radians per second, from as low to as high a speed as may be visualized. At each run the armature circuit voltage is varied and then the field is adjusted to hold the desired speed. An upper limit of armature voltage will be reached when with a saturated field the speed may no longer be held down to the desired level. A lower limit of speed is reached when the armature voltage is so low that the desired speed cannot be reached. At low levels only the residual field is needed.

A family of curves with various fixed speed lines is eventually reached which plots rotational loss power versus armature circuit voltage.



A. S. E. E. Annual Meeting June 1977

NEW MODULAR COURSES IN ELECTRONIC TECHNOLOGY

by

Robert F. Coughlin
Wentworth Institute - Boston, Mass.

Abstract

This paper describes the development of a series of modules of instruction that integrate concepts of instrumentation and applications with conventional topics in an introductory course for electronic technology students. The modules are laboratory oriented, multilevel and developed around transducers, ICS and other contemporary components. They are being developed by the Technical Curriculum Development Project at the Massachusetts Institute of Technology under a grant from the Imperial Organization for Social Services of Iran. Material from some of the modules has been class tested at Wentworth Institute.

Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

INTEGRATING INTERPERSONAL DYNAMICS WITH A TRANSPORTATION ENGINEERING DESIGN PROJECT

Ronald W. Eck
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Recently, there has been concern for providing additional design courses for civil engineering undergraduates. Thus, there are now many cases where students work in teams solving open-ended problems. While such projects provide the student with an opportunity to function in a realistic engineering design group situation, there are certain attributes, primarily interpersonal communication abilities and leadership skills, which normally are not dealt with explicitly. As a result, most civil engineering students complete their baccalaureate requirements with little or no supervised experience in effective communication in a small group setting.

The author has developed a plan for incorporating interpersonal relations and communication as an integral part of a transportation engineering design project. A class of approximately 30 civil engineering seniors in a highway engineering course is randomly divided into small groups consisting of from four to six individuals. Initially, several class periods are spent discussing basic ideas related to interpersonal communications. For example, students learn to recognize and to make meaningful contributions to group activities. At this time, the student teams have an opportunity to begin practicing some of these skills while becoming acquainted with each other.

The remainder of the semester is spent designing a four-mile section of highway, from the route location stage through preliminary cost estimates. A guided design approach is used for the project based on instruction-feedback material prepared by the author. Although most of the time is spent on the technical aspects of the project, all teams conduct weekly self- and group-evaluations. Results of these evaluations are discussed among group members and charts are kept to record team progress and attitudes as a function of time.

Communication skills and interpersonal dynamics are also involved in the later stages of the course. A final requirement of the course is that each student group make a formal oral presentation of the project to the class. After reviewing the projects, the instructor gives each group a numerical grade for the project. It is left up to the students to distribute these points among themselves.

Although student growth in the area of interpersonal dynamics has not been as great as might be desired, the author believes that it is worth sacrificing some technical content in order to achieve student development in these skills. Such development will play an important role in the student's professional career where interaction in small groups is extremely important. Based on student and faculty feedback, modifications continue to be made to the plan to increase its overall effectiveness.

Title:	Comprehensive Project for Civil Engineers, CE 291
Author's Name:	Edward S. Neumann
Author's Affiliation:	Associate Professor, Department of Civil Engineering
Author's Address:	West Virginia University Morgantown, West Virginia 26506

The purpose of the three-credit hour course (two hours of class and a three-hour lab per week) is to apply "civil engineering principles, through group studies, to develop a solution for a comprehensive engineering problem." The course attempts to undertake open-ended civil engineering design problems from the real world and apply standard problem-solving approaches. Emphasis is placed on a final project report in both written and oral form, representing the entire class. Systems analysis, operations research concepts are introduced depending on the nature of the problem. Design research from library references is often necessary. Several projects have been joint efforts with students from landscape architecture design courses. Instructors from the respective courses worked together to plan the work program. Also, a unique feature of the course has been the utilization of outside "consultants." Attempts are made to develop initial sets of design solutions by mid-semester. The designs are presented to outside experts and interested parties for review and comment. The comments are then utilized to modify and narrow the range of solutions examined in the last half of the semester. Project topics to date have included park design, low volume roads, solid waste collection and disposal, subdivision design, and housing codes.

EXPERIENCES WITH DISSECTIBLE ELECTRICAL MACHINES AND TRANSFORMERS IN WVU POWER LABORATORY INSTRUCTION

by

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West Virginia University (WVU) has been using dissectible electrical machines made by Feedback Inc., and dissectible transformers manufactured by Hampden Engineering Corporation for laboratory instruction in the first course in Electric Power (Electromechanical Energy Conversion, EE 130). What are our experiences with them after incorporating these into some experiments for the past four semesters? As with most things there are merits and demerits in their use. These are presented below:

Dissectible Machines: Students who are not familiar with ac and dc energy conversion devices are able to get a good understanding of the structure of different types of machines. They like the hands-on experience they get in configuring these machines. Because of the fragile nature of some elements of the assembly, we found that it is not advisable to let the students work on their own with these devices. It has also been found that it is not easy to get stable and reasonable sets of readings to draw performance characteristics resembling the characteristics of large scale machines. These devices are better designed to operate as dc machines than as ac machines. We strongly feel that these machines are good supplements but not replacements for classical laboratory machines (5 h-p size). While the former are ideal for the students to comprehend the internal working of the electrical machines, the latter are still recommended for obtaining their terminal characteristics.

Dissectible Transformers: Unlike the machines, the transformers are extremely useful for teaching the students, not only their internal parts, but also for performing the usual tests on them and obtaining their characteristics. The students can also vary the magnetic characteristics of the iron core by simulating several air gaps. Thereby the students could appreciate the working of magnetic circuits, which usually turns off students from getting interested in electric power/energy discipline.

It has been found that the students have better appreciation for electric machines and transformers after working with the dissectible models and therefore they are more highly motivated.

A Basic Self Learning Electrical Engineering Laboratory

by
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Worcester Polytechnic Institute
Worcester, MA 01609

The laboratory program consists of a number of basic measurement experiments and simple projects. Of the basic experiments the following five are required of each student:

- Measurements using the CRO (8 Units)
- Using the dc and ac panel power supply (3 Units)
- Using a multimeter (7 Units)
- Measurements involving linear and nonlinear components (7 Units)
- Power measurements, single and 3-phase (4 Units)

A detailed syllabus with specific laboratory instructions is provided. The number of units assigned to each experiment depends on its length and is roughly equivalent to the number of hours required for completion.

At least two additional experiments of a project nature, such as building an ohmmeter, a tachometer, devices involving neon lamps, etc. are required.

For each student three 3-hour supervised periods per week and a number of open laboratory periods are scheduled. Students perform their work at their own pace.

Evaluations are done on an individual basis after the student has completed an experiment. During a 1/2 hour conference with a faculty instructor, the student's laboratory workbook is inspected and the student is asked to perform simple measurements, demonstrate the operation of his device and answer questions on his work. No formal laboratory reports are required.

In order to pass the course the work has to be completed during the 7-week term. It can be continued in a successive term if two additional experiments are performed.

The final course grade depends on the assigned experiment grades and the number of experiments performed by the student.

A Time - Shared Communications Laboratory

by
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Developed under a grant from the National Science Foundation, Grant GZ-3330, this modern data communication laboratory eliminates the need for multiple "set-ups" of sophisticated hardware by time-sharing each bench station to one such "set-up". This is made possible through the use of a Datel System 256 data acquisition/distribution system (Datel Systems Inc., Canton, MA 02021) which is connected to each bench station by a "transmit" and a "receive" coaxial cable. All critical processing of signals in each experiment is done by digital logic circuitry located at the System 256. The analog signals are acquired from the benches, A/D converted, processed, D/A converted, and returned to the benches in an analog format.

The laboratory does not degenerate into a demonstration, as there is still ample hardware implementation required at the benches. Throughout the duration of the term the students will have to design and build several low-pass filters, an approximate to a matched filter, a data synchronization circuit, and a digital data detector. This time-shared operation provides an excellent opportunity to conduct an experiment on (time-division) MULTIPLEXING. In this experiment the students are actually allowed to operate the Datel System 256, connecting the benches pairwise for two-way voice communication. The other experiments in the laboratory are entitled QUANTIZATION, SAMPLING, INTERSYMBOL INTERFERENCE, AND BIT ERROR MEASUREMENTS; in these experiments the benches are "connected" in a self-loop to the Datel System 256. The laboratory runs in conjunction with the undergraduate course on Electrical Communication Engineering.

The Independent Laboratory: - The Use of the Laboratory in Providing Enrichment to Engineering Curricula

Donald M. Roberts
Department of Chemical Engineering
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Iowa State University
Ames, Iowa 50010

The laboratory is generally used in engineering programs to introduce students to equipment, to testing and research procedures, to techniques for presenting information through report writing and to error analysis. The laboratory is also used, almost without exception, to demonstrate concepts discussed in an associated lecture program and is thus tied in to well established parts of the curriculum. This connection is not always necessary or desirable. The laboratory can be used to present ideas which fall outside the "essential" parts of the program. It thus becomes independent of existing lecture courses and can provide enrichment by permitting study of timely subjects, of subjects of student concern, and of subjects for which no time is otherwise available.

To be independent, the laboratory must be totally self-contained with lecture delivered, hand outs available, equipment demonstration performed, experiment carried out, and data gathered during the assigned period. To be successful the experiments must be well thought out, the equipment better than merely adequate and the instructor unusually well informed about the subject and the operation of the apparatus. These requirements would be too demanding if the full load fell on one person. The solution successfully tried at ISU was to enlist the support and assistance of people and equipment associated with other departments.

The concept of the independent laboratory used for enrichment, was tested at Iowa State University as part of a 3 quarter sequence in nuclear engineering for non-nuclear engineering majors. Among the many topics which had to be excluded from the material covered in the lectures was the fabrication of oxide fuel pellets. In view of the "materials" interest of some of the students and the subject's obvious importance, one type of reactor fuel fabrication was simulated by making Al_2O_3 pellets during the two hour laboratory period. Sintering was discussed, the provided powder was sieved, weighed samples were mixed with various binders, and a collection of green pellets were formed at various pressures. The pellets were fired by the instructor and made available to the students for measurements and examination before the next laboratory meeting. The knowledge and enthusiasm of the instructor, the smooth way in which the laboratory exercise progressed added a great deal to an enriching experience for the students.

APPENDIX

LISTING OF LABORATORY AREAS

AEROSPACE ENGINEERING

Aerodynamics
Aerophysics
Aerospace
Anemometry
Boundary Layer Measurements
Wind Machines
Wind Tunnel Experiments

AGRICULTURAL ENGINEERING

Agricultural Machinery
Agricultural Structures
Animal Productivity
Animal Waste Management
Biological Materials
Electrification
Environmental Conservation
Erosion Control
Fluid Power
Grain Drying
Ground Water Hydrology
Irrigation and Drainage
Mechanization
Plant and Animal Environments
Small Engines
Soil and Water Conservation

BIOENGINEERING

Bioelectronics
Bioinstrumentation
Biomedical Engineering
Biomedical Fluid Mechanics
Holography
Medical Electronics
Medical Instrumentation

BIOLOGY

CHEMICAL ENGINEERING

Air Pollution
Biochemical
Bituminous Technology
Catalysis
Chemical Kinetics
Chemistry
Control Theory
Electrochemistry
Environmental
Fluid Flow
Fluid Mechanics
Heat Transfer
Heat and Mass Transport
Kinetics
Mass Transfer
Momentum Transfer
Plant Design
Polymer Science
Process Control
Process Dynamics
Pulp and Paper
Reaction Engineering
Reaction Kinetics
Rubber Technology
Scale-Up Methods
Separation Processes
Thermodynamics

CHEMICAL ENGINEERING (CONT.)

Unit Operations

CHEMISTRY

CIVIL ENGINEERING

Aerosols
Air Sampling and Analysis
Applied Mechanics
Architectural
Asphalt
Atmospheric Chemistry
Bituminous Technology
Concrete
Concrete Masonry
Concrete and Steel
Construction Management
Construction Materials
Ecological Systems
Environmental
Fluid Mechanics
Foundations
Geodesy
Geology
Geotechnics
Hydraulics
Hydraulic Models
Hydrology
Management
Materials
Mechanics of Materials
Micro-Materials
Pavement
Photogrammetry
Properties of Concrete and Steel
River Behavior
Sanitary Engineering
Sediment Transport
Soil Mechanics
Solar
Steel
Strength of Materials
Structural Design
Structural Engineering
Structural Mechanics
Surveying
Traffic Engineering
Transportation Engineering
Urban Engineering
Waste Water
Waste Treatment
Water
Water Analysis (Physical, Chemical, and Biological)
Water Chemistry
Water Resources

COMPUTER SCIENCE

Analog
Analog Computer
Computer Applications
Computer Architecture
Computer-Based Instrumentation Systems
Computer Graphics
Computer Languages
Computer Methods
Hybrid Computer

COMPUTER SCIENCE (CONT.)

Input/Output Devices
Memory Devices
Programming
Storage Devices

ELECTRICAL ENGINEERING

Active Networks
Analog/Digital Conversion
Analog Electronics
Analog Signal Processing
Artificial Intelligence
Audio Engineering
Circuits
Communications
Communications Systems
Control Systems
Cybernetics
Digital Circuits
Digital Design
Digital Electronics
Digital Integrated Circuits
Digital Logic
Digital Signal Processing
Digital Systems
Digital Transducer Devices
Electric Power
Electrical
Electrical Machines
Electromagnetic Waves
Electronic Design
Electronics
Electrophysics
Feedback Systems
Image Transmission
Inertial Systems
Input/Output Devices
Instrumentation
Integrated Circuits
Laser Systems
Linear Amplifier
Linear Integrated Circuits
Logic Design
Magnetohydrodynamics
Measurements
Microcomputers
Microelectronics
Microprocessors
Microwaves
Mini-Computers
Network Analysis
Network Synthesis
Optical Communications
Optical Design
Optics
Optimization
Pattern Recognition
Plasma Physics
Power Devices
Power Systems
Protective Relaying
Psychoacoustics
Radio Frequency
Rotating Machinery

ELECTRICAL ENGINEERING (CONT.)

Semi-Conductor Devices
Servomechanisms
Signal Processing
Signal and System Interaction
Simulation of Communications Systems
Software
Solid State
Solid State Electronics
Solid State Integrated Circuits
Spectral Analysis
Strobe
Superconductivity
Transformers
Transmission Lines

GEOLOGICAL ENGINEERING

Fuels
Geological
Mineral Dressing
Mineral Processing
Mineralogy
Petrology
Petroleum
Petroleum Engineering
Physical Geology
Reservoir Fluid Properties
Rock Mechanics
Sedimentology

GRAPHICS

Architectural Drawing
Computer Graphics
Design
Drafting
Engineering Drawing
Engineering Graphics
Freshman Design
Graphic Design
Interactive Graphics

INDUSTRIAL ENGINEERING

Computer Simulation
Economic Systems
Facilities Planning
Human Factors
Industrial Hygiene
Modelling
Organizational Design
Organizational Theory
Policy Design
Planning
Simulation
Socio-Economic Service Systems
Socio-Technical Systems
Systems Design
Systems Engineering
Work Systems

MATERIALS SCIENCE

Casting
Ceramic Processing
Corrosion
Die Design
Electrical and Magnetic Properties
Electron Diffraction
Electron Microscopy
Foundry
Foundry Operations
Glass
Manufacturing Shop

MATERIALS SCIENCE (CONT.)

Materials
Materials Characterization
Materials Testing
Mechanical Properties
Metals Casting
Microstructure Analysis
Microscopic Techniques
Optical Properties
Particulates
Pattern Shop
Physical Metallurgy
Spectrophotometry
Tool Design
X-Ray Diffraction

MECHANICAL ENGINEERING

Acoustics
Automatic Control
Combustion
Computer Aided Design
Computer Aided Manufacturing
Controls
Corrosion
Creep
Cryogenics
Data Analysis
Design
Design Projects
Design Studio
Dynamics
Ecological Systems
Electrochemical Mass Transfer
Energy
Energy Conversion
Energy Systems
Engineering Design
Engineering Mechanics
Environmental
Experiment Design
Experimental Stress Analysis
Fire
Fluid Mechanics
Fluidics
Fracture Mechanics
Gas Dynamics
Geophysical Flow
Heat Transfer
Holography
Impact
Instrumentation
Internal Combustion Engines
Lubrication
Machine Design
Manufacturing
Manufacturing Methods
Materials
Materials Fracture and Fatigue
Materials Testing
Mechanics
Mechanisms
Metal Processing
Noise
Numerical Control
Optical Diagnostics
Photoelasticity
Photomechanics
Pneumatics
Power
Pumps
Refrigeration
Similitude
Solar Energy
Solid Mechanics
Sound

MECHANICAL ENGINEERING (CONT.)

Strength of Materials
Stress Analysis
Systems
Systems and Controls
Systems Simulation
Thermal Engineering
Thermal Science
Thermodynamics
Thermofluids
Tribology
Turbine Tests
Turbomachinery
Turbulent Flow
Vibration
Wear

NUCLEAR ENGINEERING

Accelerator Design
Dosemetry
Fission Physics
Instrumentation
Neutronics
Non-Destructive Testing
Nuclear Interactions
Nuclear Power
Nuclear Reactors
Radiation Data
Radiation Detection
Radiation Instrumentation
Radiation Measurements
Radiochemistry
Reactor Dynamics
Spectroscopy
Spectrum Unfolding

OCEAN ENGINEERING

Fluid Flow
Hydrodynamics
Marine Engineering
Meteorology
Naval Architecture
Ocean Engineering
Oceanography
Ship-Hydrodynamic Experimentation
Ship-Structure Experimentation
Submarine Soil Analysis
Undersea Systems
Underwater Acoustics
Vibrations

LISTING OF LABORATORY CONTACT PERSONS

Institution	Dept.	Contact Person
Univ. Akron	ChE	L. G. Focht
Univ. Alabama	Eng	W. E. Lear
Univ. Alabama, Birmingham	Eng	C. Rubin
Univ. Alaska	Eng	J. A. Zauling
Arizona State Univ.	Eng	B. D. Wood
Univ. Arizona	Aero/ME	L. B. Scott
	IE	D. Schultz
	CE	M. Stephenson
Bradley Univ.	ME	M. A. Wessler
	EE	T. Stewart
Univ. Bridgeport	ME	R. S. Pressman
Brigham Young Univ.	Eng	C. S. Barton
Univ. British Columbia	Eng	F. Berry
Brown Univ.	Eng	S. Karlsson
California Poly. San Luis Obispo	EE	W. Finchum
California Poly. Pomona	Eng	B. Davison
California State Univ., Long Beach	Eng	R. L. Alexander
California State Univ.. Los Angeles	EE	R. Ramchandani
California State Univ., Northridge	ME	L. S. Caretto
	EE	V. P. Cable
Univ. California, Berkeley	Eng	T. Lapsley
Univ. California, Davis	ChE	R. L. Bell
	CE	E. D. Schroeder
	EE	E. W. Owen
Univ. California, Irvine	Eng	R. Schinzinger
Univ. California, Los Angeles	Mech/Struct	A. Charwat
	Eng Syst	A. B. Rosenstein
Capitol Inst. Technology	Eng	G. W. Troxler
Carnegie-Mellon Univ.	CIT	D. Tuma
	ME	R. Komanduri
Clemson Univ.	Eng	B. E. Gilliland
Cogswell College	Eng	T. Prendergast
Colorado Technical College	Eng	T. J. Forster
Univ. Colorado	Eng	M. Anderson
Columbia Univ.	Eng	P. W. Likens
Univ. Connecticut	Eng	S. L. Rice
Cooper Union	Eng	C. Tan
Cornell Univ.	Agric.	R. B. Furry
Dartmouth College	Eng	C. F. Long
Del Mar College	EE	J. Zazvorka
Univ. Detroit	Eng	N. Bow
DeVry Inst. Technology	EE	J. Canavan
Univ. Evansville	Eng	R. L. Devoshier
Fayetteville Technical Inst.	Eng	A. King
Florida Technological Univ.	Eng	D. L. Block
Florissant Valley Community College	Eng	V. J. Cavanaugh
Harvard Univ.	Eng	F. H. Abernathy
Harvey Mudd College	Eng	J. R. Phillips
Univ. Hawaii	Eng	J. Fox
Univ. Houston	ChE	F. L. Worley
	Eng	G. H. Koopman
Univ. Illinois, Urbana-Champaign	Agric.	D. Hunt
	CE	J. D. Haltiwanger
	NE	B. W. Wehring
Iowa State Univ.	ChE	A. H. Pulsifer
	Eng Sci	B. R. Munson
	NE	R. Hendrickson
	IE	K. L. McRoberts
	Matls Sci	D. R. Wilder
	EE	J. O. Kopplin
Univ. Iowa	Eng	E. M. Mielnik
Lake Superior State College	Eng	R. W. Curtis
Louisiana Tech Univ.	Eng	J. Thigpen
Lehigh Univ.	ME	S. H. Johnson
Marquette Univ.	Eng	R. J. Kipp

Institution	Dept.	Contact Person
Univ. Manitoba	Eng	R. Cahoon
Univ. Maryland	Aero	J. D. Anderson
	Fire	J. L. Bryan
	CE	E. C. Carter
	ME	P. F. Cunniff
	EE	R. O. Harger
	ChE	A. Gomezplata
Massachusetts Inst. Technology	Eng	L. A. Gould
Univ. Massachusetts	Eng	J. S. Marcus
McGill Univ.	ChE	O. M. Fuller
Univ. Miami	EE	G. Gonzales
	Eng	J. Catz
Michigan State Univ.	Eng	W. N. Sharpe, Jr.
Michigan Technological Univ.	ME	G. L. Scofield
Univ. Michigan	Eng	J. G. Eisely
Mississippi State Univ.	Eng	L. R. Hester
Univ. Mississippi	Eng	R. L. Henry
	ChE	L. F. Roy
	ME	K. F. Wylie
Univ. Missouri, Columbia	Eng	W. L. Carson
Univ. Nebraska, Lincoln	Eng	H. R. Walters
Univ. Nebraska, Omaha	Eng	C. O. Smith
New Hampshire Technical Inst.	Eng	A. E. LeBlanc
Univ. New Haven	ME	R. J. Greet
New Jersey Inst. of Technology	ChE	A. J. Perna
New Mexico State Univ.	Eng	C. Q. Ford
Univ. New Mexico	Eng	C. F. Hawkins
City College, City Univ. New York	Eng	D. Eitzer
	ChE	R. Shinnar
State Univ. New York, Maritime College	Eng	R. Burke
New York State College of Ceramics	Eng	J. L. Burdick
North Carolina State Univ.	Eng	R. F. Davis
Univ. North Carolina, Charlotte	Eng	R. R. Phelps
Northern Arizona Univ.	Eng	A. Gill
Univ. Notre Dame	Eng	M. Delich
Norwich Univ.	Eng	C. Renfrew
Oakland Univ.	Eng	H. R. Witt
Ohio Northern Univ.	Eng	J. R. Smith
Oklahoma State Univ.	Eng	R. L. Lowery
Oregon State Univ.	ME	J. R. Kinney
Univ. of the Pacific	Eng	E. B. Evans
Pennsylvania State Univ.	Eng	W. G. Braun
Univ. Pittsburgh	Eng	R. Bonn
Univ. Portland	Eng	T. J. Nelson
Univ. Puerto Rico, Mayaguez	ChE	A. Rodriquez
Purdue Univ. West Lafayette	Eng	M. B. Scott
Purdue Univ., Calumet	Eng	D. G. Skitek
Queen's Univ.	Eng	P. H. Wittke
Rensselaer Polytechnic Inst.	Eng	P. M. DeRusso
Rice Univ.	Eng	A. J. Chapman
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Rose-Hulman Inst. of Technology	Eng	R. Steinhauser
Rutgers Univ.	Eng	B. Pelan
San Diego State Univ.	ME	N. A. Hussain
San Jose State Univ.	Eng	W. Venuti
City College of San Francisco	Eng	J. Lallas
Seattle Univ.	Eng	F. P. Wood
Universite de Sherbrooke	Eng	D. Proulx
Univ. South Carolina	ME	L. Connor
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Univ. Texas, Austin	EE	C. H. Roth
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Univ. Toledo	CE	G. J. Murnen
Tulane Univ.	Eng	H. H. Sogin
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United States Coast Guard Academy	Eng	G. P. Vance
United States Naval Academy	Eng	J. H. Halford
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Washington Univ.	ME	D. A. Peters
Waterbury State Technical College	Eng	K. E. DeRego
Univ. Waterloo	Eng	R. G. Van Heeswijk
Wayne State Univ.	Eng	K. H. E. Kroemer
West Virginia Univ.	Eng	B. Atchley
Wichita State Univ.	Eng	A. R. Graham
Widener College	Eng	R. D. Swope
Univ. Wisconsin, Milwaukee	EE	H. P. Boettcher
	ME	D. E. Niles
Univ. Wisconsin, Platteville	ME	R. Fielder
Worcester Polytechnic Inst.	Eng	J. W. Matthews
Yale Univ.	Eng	P. Kindlmann
Youngstown State Univ.	Eng	V. A. Richley

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U of Pacific	EE	Pulleyblank, R
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Wentworth Inst		Kelly, R
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Stevens Inst	ME	Cole, R
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Union College	Math	Hanselman, J

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U of NM	ME	Feldman, K

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City College NY	Tech	Goodlet, J
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Merchant Marine		Burghardt, M
Nassau City C		Kitay, D
New York	Pres.A-Z	Zeisky, A
NYCC		Albano, R
Pratt Inst	Act Dn	Seidman, A
Queensbrough CC		Kantrowitz, P
Queensbrough CC		Kousourou, G
Rensselaer	EE	Carlson, A
Staten Is CC		Fazzolari, C
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Ohio State U	CE	Larew, R
Ohio State U	CE	Mintzer, O
Ohio State U	Cer E	Semler, C
Ohio U	IE	Zwahlen, H
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U of Cinncinati	Met E	Tholke, W
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Youngstown State U	EE	Munro, P

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U of Oklahoma		Gollahalli, S
U of Oklahoma	EE	Kuriger, W
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Oregon State U	ME	Larson, M
Oregon State U	EE	Weber, L
Oregon Tech	Process	Marostica, G
Portland State U	EE	Killian, T
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Carnegie-Mellon	EE	Tuma, D
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Gannon	Dn	Kosar, H
Penn State		Ciavarella, T
Penn State	ME	Laananen, D
Penn State-Ogontz		Byerly, H
Temple U	E Tech	Hrusovsky, V
Temple U	ME	Reeves, T
Temple U	Lab Coor	Pfeffer, H
U of Penn	ME	Paul, B
U of Penn	CE	Roll, F
U of Pittsburgh	CE	Mangelsdorf, C
Westmoreland CC	Welding	Rudolph, W

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Prairie View A&M		Sohel, M
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Texas A&M	EE	Gorakhpurwalla, H
Texas A&M	Ag E	Ruff, J
Texas Tech	EE	Gustafson, D
Texas Tech	EE	Walkup, J
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U of Houston	ME	Cox, J
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